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Mossman, Robert Cockburn
Southern Hemisphere seasonal correlations

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Southern Hemisphere Seasonal Correlations.

BY

R. C. MOSSMAN, F.R.S.E.

[*Reprinted from "Symons's Meteorological Magazine," Vol.* 48, *1913.*]

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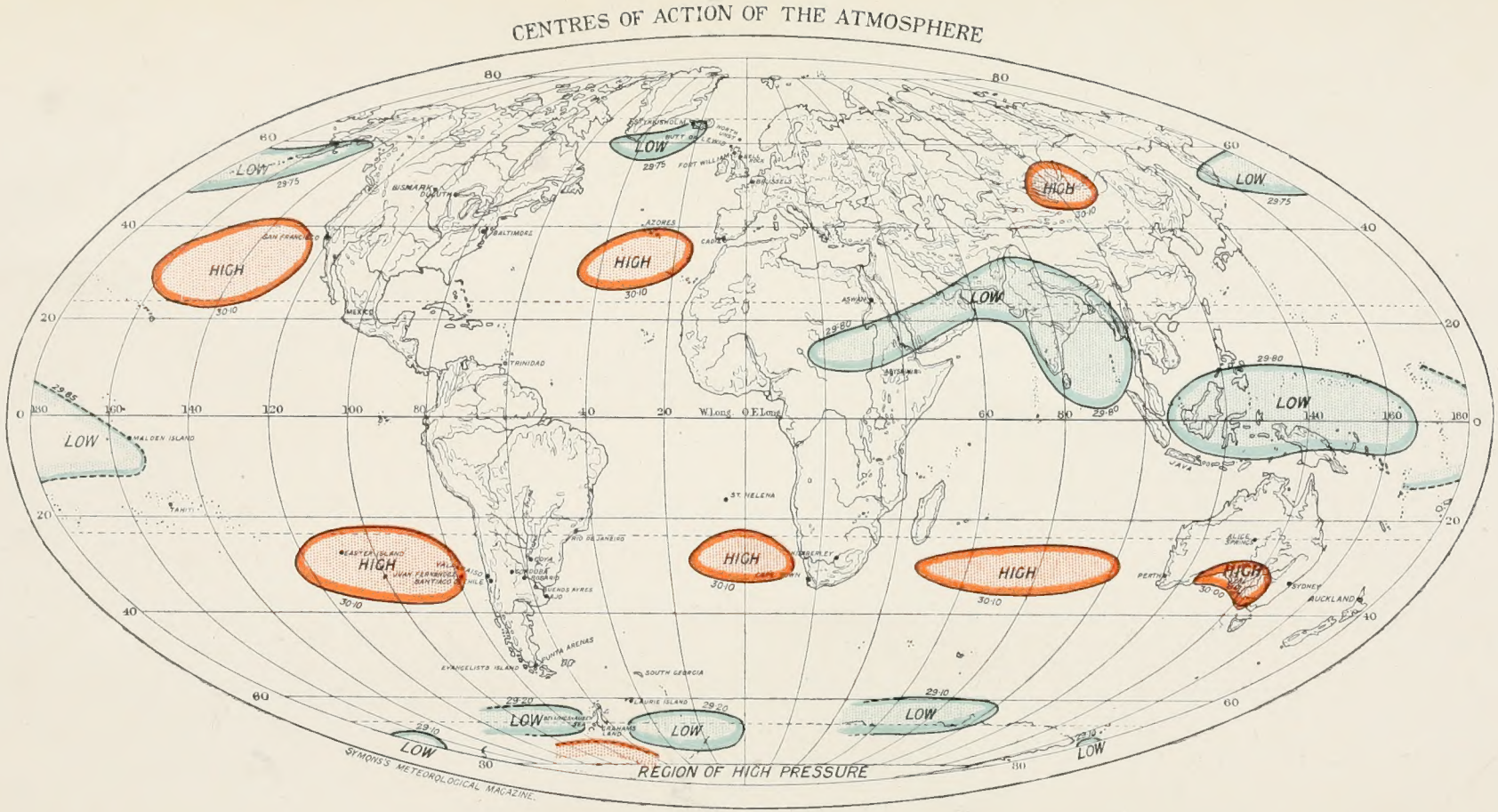

THE ABOVE MAP SHOWS THE MEAN ANNUAL AREAS OF HIGH AND LOW PRESSURE FORMING THE PRINCIPAL "CENTRES OF ACTION" OF THE ATMOSPHERE, WITH THE POSITIONS OF THE PLACES REFERRED TO IN THE ARTICLES ON SOUTHERN HEMISPHERE SEASONAL CORRELATIONS.

SOUTHERN HEMISPHERE SEASONAL CORRELATIONS.

By R. C. Mossman, F.R.S.E.

Introduction.

The subject of synchronous compensation between the types of seasons at places situated in different parts of the Earth, and of the relation that exists between the sequence of weather at one place with the weather following at another place, even when the two localities are situated at a great distance from one another, is one that has of late years received increasing attention at the hands of meteorologists. Hildebrandsson, among a score of workers at this fascinating class of research, stands pre-eminent for his numerous contributions. In four papers on the "Centres of Action of the Atmosphere," he has given a large number of examples of this species of weather correlation, most of which refer to places in the northern hemisphere, where we possess many of the long and homogeneous series of observations so necessary for this form of research. In his fourth and last memoir * Hildebrandsson has carried his investigations into the southern hemisphere, being hampered considerably by the absence of data from regions where the southern "centres of action" are located. Having of late begun to collect data for South America with the object of preparing a general memoir on the climatology of that Continent, a considerable mass of material is already available for testing whether the South American weather sequences show as pronounced resemblances or contrasts when compared with data from other regions, as do those in the northern hemisphere. Cordoba in the Argentine Republic, it would appear, is the only station in South America with a long record situated in what may prove to be an "action centre," most other places referring to regions located in a transitional zone. While for the purposes of the present inquiry there is a lack of data from pronounced "action centres," still many of the stations are so placed that they serve as an index of the pulsations taking place in the neighbouring foci of cyclonic and anti-cyclonic activity. As will be apparent later, some of the correlations obtained lend considerable support to the opinion expressed by other workers that the "action centres" of the globe are mutually associated, and that abnormal conditions in one hemisphere are inter-twined, not only with simultaneous but in many cases subsequent exceptional features in the other half of the earth.

RELATION BETWEEN NILE FLOOD AND MAY TO AUGUST RAINFALL AT SANTIAGO (CHILE).

The height of the Nile flood, as has been shown by Captain Lyons,† is dependent on the June to September rainfall in Abyssinia. A

* Reviewed along with third paper in Symons's Magazine, Vol. **45**, p. 236.

† *Quar. Jour. Roy. Met. Soc.*, Vol. **36**, p. 215.

relation is apparent if we compare the volume of the water passing Aswan between July 1st and October 31st with the corresponding southern winter rainfall of Santiago de Chile (Lat. 33° 27′ S., Long. 70° 42′ W., height 1,703 feet above sea). The data utilised for the Nile represent the ratios of the annual floods to a mean flood during the years 1869 to 1906. They are given in Captain Lyons' publication "The Rains of the Nile," 1906. The rain data for Santiago (see table I.) are taken from the series of volumes and reports issued by that Observatory or from the reports of the recently established Meteorological and Geophysical Institute. The mean rainfall during the four months, May to August, at Santiago during the 38 years 1869-1906 is 11·82 inches, or 81 per cent. of the total annual fall. The relation between the Nile floods and the Santiago rainfall for each year from May to August in this period is as follows, the normal being taken as equal to 100 :

Year.	Nile.	Santiago.	Year.	Nile.	Santiago.	Year.	Nile.	Santiago.	Year.	Nile.	Santi. ago.
1869	118	39	1879	114	54	1889	100	72	1899	63	248
1870	123	63	1880	98	206	1890	120	51	1900	89	237
1871	105	69	1881	93	101	1891	101	166	1901	87	118
1872	111	44	1882	84	96	1892	120	32	1902	63	153
1873	84	81	1883	104	87	1893	99	66	1903	89	55
1874	126	54	1884	83	78	1894	122	58	1904	75	185
1875	110	52	1885	99	106	1895	115	67	1905	65	192
1876	109	39	1886	91	25	1896	106	62	1906	87	92*
1877	70	116	1887	119	148	1897	89	107			
1878	125	78	1888	72	175	1898	106	126			

These results are graphically shown in the following diagram :

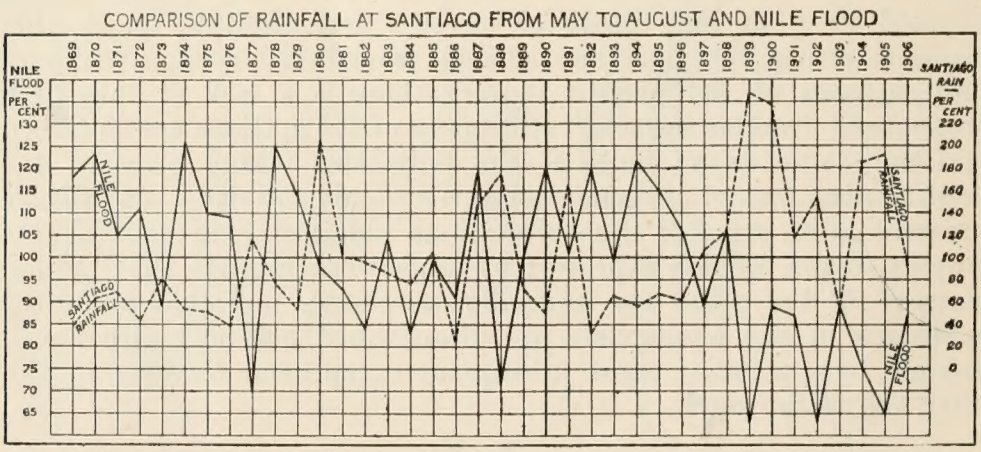
COMPARISON OF RAINFALL AT SANTIAGO FROM MAY TO AUGUST AND NILE FLOOD
NILE FLOOD PER CENT
SANTIAGO RAIN PER CENT
NILE FLOOD
SANTIAGO RAINFALL
SANTIAGO RAINFALL
NILE FLOOD

FIG. 1.

* It may be of interest to give the ratio which the Santiago rainfall during the last six years (period May to August) bears to the normal, 1869-1906. The values are, 1907, 64%; 1908, 51%; 1909, 48%; 1910, 76%; 1911, 38%; 1912, 86%. We should, therefore, expect the Nile Floods of these years to be above normal, except possibly in the year 1907 when many well established correlations broke down.

The co-efficient of correlation deduced from these figures is ·62* and the probable error ·07.

The diagram shows that there is on the whole a strongly pronounced opposition between the height of the Nile flood and the winter rainfall at Santiago. During certain groups of years the opposition is relatively weak, but in general the two curves present a strong contrast to each other. The winter rainfall at Santiago in common with other stations between the parallels of 32° and 39° south latitude, especially on the littoral, varies with the position of the South Pacific high pressure area. Antarctic observation, notably those of the "Belgica" in 1898-1899 and of Dr. Charcot in the years 1904 and 1909, show an undoubted sea-saw movement of pressure at this season between the South Pacific anticyclone and the corresponding low pressure area situated at the latitude of the Antarctic Circle in the southern extension of the South Pacific, known as the Bellingshausen Sea.† In some years this low pressure belt is deflected to the west owing to the extension northward of a portion of the Antarctic anticyclone over Graham's Land, which is located on the Cape Horn meridian. Under these conditions cyclonic systems instead of pursuing their normal path south of Cape Horn, approach the coast of Chile in low latitudes, bringing increased rainfall and high temperatures, due to the prevailing northerly winds, over the Santiago region. On the other hand, when the South Pacific anticyclone is south of its normal position, the Antarctic anticyclone recedes, the cyclonic area to the west of Graham's Land is deepened, so that the storm centres pass far to the

* We can carry the comparison of the relation of the Nile Flood—Santiago rainfall back to 1849 by means of the data giving the mean reading of the gauge at the Delta Barrage for the months July to October (see Craig—"A Meteorological Triangle," *Quar. Jour. Roy. Met. Soc.*, Vol. **36**, p. 352). Previous to 1867 only the mean *annual* totals of Santiago rainfall are available, but as four-fifths of the yearly quantity falls from May to August, the data are fairly comparable with the Nile data. There are no annual rain totals for Santiago in 1851 and 1852, and no Nile data for 1859, but taking the 17 years common to both series in the period 1849-1868, we obtain a negative correlation co-efficient of ·66, and a probable error of ·09. The Santiago rain totals for these years are taken from the following publication, issued by the Santiago Observatory, viz. :—"*Seccion de Meteorologia*, Santiago de Chile, 1901, page 117." The ratios referred to the means of the 17 years, 1849-50, 1853-58, 1860-68, are as follows :—

Year.	Nile.	Santiago.	Year.	Nile.	Santiago.	Year.	Nile.	Santiago.
1849	97	81	1857	93	58	1864	102	140
1850	96	141	1858	89	158	1865	96	66
1853	106	54	1860	98	131	1866	112	42
1854	111	118	1861	117	93	1867	97	61
1855	86	139	1862	100	107	1868	80	152
1856	107	140	1863	112	22			

† See papers by the writer in *Scottish Geographical Magazine*, August, 1910, and pp. 411-416, and *Journ. Scot. Met. Soc.*, Vol. **15**, pp. 317-318.

TABLE I.—*Rainfall at Santiago, Chile, 1867–1911.*

YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	YEAR.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1867	...	...	...	·10	1·21	3·14	3·71	·71	·02	...	·26	·22	9·37
1868	..	...	...	·92	·69	2·93	5·62	2·12	9·83	1·10	...	·35	23·56
1869	...	...	·39	...	1·72	·06	1·65	1·19	·51	·35	...	...	5·87
1870	...	...	·20	...	·92	4·44	2·01	·11	·03	·34	...	...	8·05
1871	...	·70	·83	·53	2·13	2·28	2·71	1·06	1·37	·23	...	..	11·84
1872	..	...	·12	...	1·72	1·46	·29	1·76	·87	...	...	...	6·22
1873	...	·06	...	·43	1·01	1·54	3·35	3·67	1·31	...	...	·24	11·61
1874	...	...	·09	...	1·83	3·59	·47	·50	1·39	·67	1·84	...	10·38
1875	·02	·65	...	·02	4·28	·68	1·17	..	...	...	·21	2·37	9·40
1876	...	..	·54	·36	1·49	·83	·61	1·67	·76	1·60	·13	...	7·99
1877	·07	·03	...	5·14	1·96	·94	10·40	·46	3·86	2·70	·01	..	25·57
1878	·15	·44	·98	4·37	3·60	2·88	1·83	·93	·45	...	·15	...	15·78
1879	...	...	...	...	1·40	2·92	·85	1·21	...	·13	...	...	6·51
1880	...	·08	·02	·32	1·13	9·24	10·59	3·52	·33	·40	·07	...	25·70
1881	·23	...	...	1·00	2·46	3·43	3·58	2·46	2·90	·79	·51	...	17·36
1882	...	·06	...	...	1·59	1·29	6·32	2·18	·34	...	·18	...	11·96
1883	·46	...	·02	·01	4·71	3·30	1·80	·48	3·03	·57	...	...	14·38
1884	...	...	1·06	1·28	·25	2·43	1·93	4·59	1·22	·35	·28	1·87	15·26
1885	·02	·04	...	·12	6·12	·31	4·30	1·84	1·89	·95	·06	...	15·65
1886	...	...	...	..	·56	·50	·71	1·23	·39	·11	·21	1·28	4·99
1887	...	·57	...	·03	·15	6·29	·12	10·96	2·31	1·13	·62	...	22·18
1888	...	...	...	·60	1·08	5·00	6·24	8·36	3·65	1·61	·76	..	27·30
1889	·06	...	...	·24	1·77	·84	4·02	1·89	·02	·12	·01	·08	9·03
1890	·09	...	·06	1·52	·21	1·50	2·49	1 90	·93	·05	...	·01	8·76
1891	...	..	...	·94	4·62	5·88	8·95	·25	...	3·33	·11	·12	24·20
1892	...	...	...	..	·35	·45	1·00	1·95	·16	·27	·70	...	4·88
1893	...	...	...	·16	2·30	2·07	2·28	1·13	·04	...	·99	·46	9·43
1894	·02	...	·61	·46	2·22	1·54	1·04	2·03	·59	·04	·05	...	8·60
1895	·01	...	·74	·43	·06	·34	1·63	5·91	1·76	·33	·21	·01	11·43
1896	...	...	·03	·10	·05	1·25	4·04	1·94	2·71	·24	...	...	10·36
1897	·08	·02	·18	·01	8·13	1·78	2·06	·77	·32	·60	...	...	13·95
1898	...	...	·01	1·82	1·17	9·57	2·58	1·67	·91	1·20	·62	·09	19·64
1899	...	·01	·04	·02	1·42	9·27	6·33	12 31	·66	·39	..	...	30·45
1900	...	·02	·85	·09	4·83	5·13	13·89	4·27	·76	2·42	...	...	32·26
1901	...	·02	·19	·02	2·80	4·32	2·67	4·16	·01	·80	·02	·01	15·02
1902	...	·18	·21	·02	4·13	5·92	7·35	·70	·32	·25	·84	...	19·92
1903	·01	...	·03	·83	1·05	3·92	1·51	·02	·04	·24	·01	...	7·66
1904	...	·04	1·42	·23	9·14	3·08	6·76	2·90	·81	·64	·12	1·89	27·03
1905	...	...	·10	·08	6·13	7·32	7·07	2·20	·86	·33	·01	·13	24·23
1906	·03	·32	...	·02	4·42	1·60	1·42	3·47	·26	...	·01	...	11·55
1907	...	·03	...	·69	2·19	3·15	1·35	·83	1·79	·37	·01	·19	10·60
1908	·02	·05	...	1·67	1·17	3·28	·34	1·23	·20	...	...	...	7·96
1909	...	...	..	·07	·43	3·50	·87	·83	1·26	·18	·01	·12	7·27
1910	...	...	·41	·62	·04	6·24	1·43	1·25	·04	·13	·31	·20	10·67
1911	...	...	...	·83	1·02	1·78	1·18	·46	·62	·01	...	·80	6·70
Mean	·03	·07	·20	·58	2·26	3·18	3·39	2·34	1·14	·56	·21	·23	14·19

south. At Santiago under these conditions dry weather accompanied by radiation cold, prevails.

Until quite recently there was no suitably placed station in the South Pacific by which to determine the relations obtaining from season to season between the South Atlantic and South Pacific high pressure belts. There is a short and in the past not very reliable record from Juan Fernandez, which last year has been equipped with a very complete set of instruments by the Chilian Meteorological Office, and is now in radiographic communication with the mainland. This, along with the observations at a new station on Easter Island (Lat. 27° S., Long. 109° W.), should give us full and immediate information regarding the seasonal oscillations in the position of the South Pacific anti-cyclone. When these data come to be compared in a few years time with data from St. Helena, I have little doubt that the chain linking up the rainfall of Abyssinia with the Antarctic circulation will be complete. If this can be established then the matter becomes of great interest to the student of Antarctic meteorology and glaciology, since from the records of the Nileometers, which embrace centuries of observations, it will be possible to obtain some idea of the sequence of weather changes for a long period in the far South Pacific during the austral winter months.

RELATION BETWEEN THE MEAN BAROMETRIC PRESSURE AT STYKKISHOLM, ICELAND. AND AT LAURIE ISLAND, SOUTH ORKNEYS, DURING THE MONTH OF MAY, 1902-1911.

In the month of May a most pronounced opposition is shown between the barometric pressure at Stykkisholm, Iceland, lat. 65° N., and Laurie Island, South Orkneys, lat. 61° S. Stykkisholm, it is almost superfluous to remark, is situated in the vicinity of the great North Atlantic "centre of action," while the South Orkneys are located a little to the N.W. of one of the most pronounced Antarctic "centres of action," viz., that in the Weddell Sea. The mean barometric pressure* at these two places for the month under review

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* For Stykkisholm data I am indebted to Captain Ryder, Director of the Danish Meteorological Institute. The South Orkney data from 1904 to 1911 are taken, by kind permission of Mr. W. G. Davis, from Vol. 17 of the *Anales* (Part II.) now in course of publication by the Argentine Meteorological Office. The 1903 data are from the *Scotia* Reports, while the value for May, 1902, is from Tafel 3 of the *Meteorologischer Atlas, Deutsche Südpolar-Expedition, 1901-1903*, von Wilhelm Meinardus und Ludwig Mecking, Berlin, 1911. I am also indebted to Dr. W. N. Shaw for St. Helena data to end of 1911, in continuation of data given in publication M.O. 203.

is as follows, the values being given reduced to sea-level and gravity at lat. 45°.

	1902. ins.	1903. ins.	1904. ins.	1905. ins.	1906. ins.	1907. ins.	1908. ins.	1909. ins.	1910. ins.	1911. ins.	Mean. ins.
Stykkisholm .... (65° N. lat.)	30·03	29·85	29·78	29·89	30·14	30·08	29·80	30·06	29·83	29·63	29·91
Laurie Island .. (61° S. lat.)	29·10	29·38	29·42	29·30	29·15	29·06	29·34	29·24	29·36	29·82	29·32

The above data are shown graphically in the following curves (Fig. 2). Expressed as departures from the normal the above values show the following deviations :—

	1902. in.	1903. in.	1904. in.	1905. in.	1906. in.	1907. in.	1908. in.	1909. in.	1910. in.	1911. in.
Stykkisholm..	+0·12	—0·06	—0·13	—0·02	+0·23	+0·17	—0·11	+0·15	—0·08	—0·28
S. Orkneys ..	—0·22	+0·06	+0·10	—0·02	—0·17	—0·26	+0·02	—0·08	+0·04	+0·50

The correlation co-efficent deduced from these values is 0·90, and probable error = 0·12.

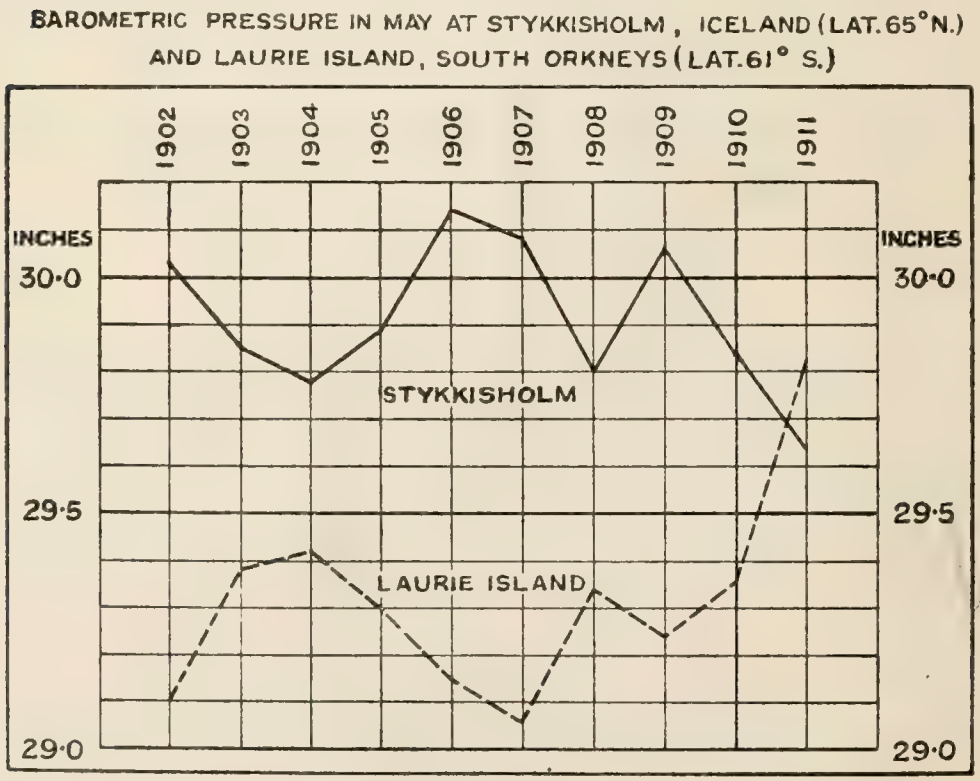

Fig. 2.

An examination of the barometric data for May at a number of stations on the South Atlantic littoral, shows that in South America, south of about latitude 47°, the pressure departures from the normal

are in harmony with those observed at the South Orkneys and South Georgia. At Punta Arenas, situated in Magellan Strait, the correlation weakens, this station being located on the wind divide that separates Pacific from Atlantic influences. Even here, however, the May pressure departures differ from those at Stykkisholm in 75 per cent. of the 23 years during which a comparison could be made (1889–1911). The physical processes that in May month bring about a high pressure in the Icelandic region, are thus associated with a lowering of pressure over the south temperate and sub-antarctic Atlantic areas. Having examined barometric data from inter-tropical regions, including St. Helena, and also from the Azores, western Europe, and the United States of America with indefinite results, I have come to the conclusion that the dominating factor influencing these May pressure variations in the North and South Atlantic is to be found in the polar regions. Owing to lack of data it has not been possible to ascertain whether the thermal equator oscillated to any extent during the month of May in the period under consideration, so as to cause changes in the general circulation of the atmosphere. As to *why* the above striking differences should obtain only in the month of May no explanation can be offered. No break has yet shown itself in the sequence, as in May, 1912, an inspection of Icelandic and south Atlantic data (the latter represented by South Georgia and Punta Arenas) shows a rise of pressure over the former and a marked fall over the latter area, when compared with the very abnormal features of May, 1911,

In order to ascertain the effect on southern wind circulation (as represented by data from Punta Arenas and the adjacent station of Evangelists Island, at the Pacific entrance to the Straits of Magellan, for both of which places we have observations of wind direction from 1899 to 1909), the May records of the two three-year groups, 1900, 1904, and 1905, and of 1899, 1902, and 1907, have been taken. At Punta Arenas the Mays of the first group show a mean departure of pressure (normal 1889-1911) of +0·181 in., and of the second group —0·213 in. The corresponding departures from the normal at Stykkisholm were —0·069 in. and +0·125 in. respectively. Similarly, to see what difference existed in the North Atlantic circulation for these two series of years, May wind data were extracted from the summaries given in the Journals of the Scottish Meteorological Society. These comprise the frequency of the wind for the whole of that country based on all the returns, for two stations in Scotland North (Bressay Sound and North Unst), for four stations in Scotland West (Cape Wrath, Butt of Lewis, Barra Head and Skerryvore), for three stations in Scotland East (Kinnaird Head, Aberdeen and Bell Rock), and finally for all England.* The values, based on observations taken twice a day, have all been reduced to percentages, and in

* See Marriott, Variations in the English Climate during the Thirty Years 1881-1910. *Quar.Jour.Roy.Met.Soc.*, Vol. **37**, July, 1911. Table I.

the following table (1) refers to the Mays of 1900, 1904 and 1905, with pressure high in the extreme South and low in the far North Atlantic, and (2) to the Mays of 1899, 1902 and 1907, when the reverse conditions of barometric pressure obtained in the regions under consideration :—

	Punta Arenas.		Evangelists Island.		Scotland.								England.	
					Whole Country.		North.		West.		East.			
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
N.	12	13	6	5	8	14	16	29	9	16	12	19	12	15
N.E.	11	12	5	3	12	14	17	21	13	16	16	19	15	13
E.	7	6	8	3	13	20	6	9	11	23	7	10	7	9
S.E.	4	0	18	6	8	8	13	9	10	10	8	10	6	7
S.	12	3	20	11	11	6	14	6	16	9	21	10	10	8
S.W.	27	11	14	15	15	10	12	7	16	10	14	10	17	12
W.	20	35	9	33	17	13	11	12	14	10	9	11	14	14
N.W.	7	20	14	24	11	10	10	6	10	6	12	10	12	12
Calm	0	0	6	0	5	5	1	1	1	0	1	1	7	10

It will be seen that in Mays with high pressure at Punta Arenas, the winds there show a marked excess (as compared with Mays in which pressure is low) from the S.W. and S., while those from W. and N.W. are in defect. At Evangelists Island where the winds are free from the effect of land disturbance, marked differences are also apparent between the two three-year groups. Here in Mays with high pressure the prevailing direction is from the south (S.E., S. and S.W.), while in Mays with low pressure the predominant winds are westerly (S.W., W. and N.W.). Without entering into details, it may be stated that in the Mays of 1900, 1904 and 1905 the barometric gradient on the S. Atlantic and Pacific coasts between the latitudes of 40° and 52½° S. latitude was only one-quarter of that observed in the Mays of 1899, 1902 and 1907, which clearly points during the first three Mays to a northward extension of the anticyclone which normally covers the south of Grahams Land south of the Antarctic circle. In the second group, embracing the Mays of 1899, 1902 and 1907, the region south of Cape Horn was the theatre of cyclonic activity, with a very steep gradient south of the 40th parallel.

In the northern Atlantic area represented by the groupings for Scotland and England, there are also pronounced variations in the wind circulation during the two groups of years. The Mays of 1900, 1904 and 1905 with pressure at Iceland below the normal, show an excess of south and south-west, and a defect of north and east winds, compared with the Mays of 1899, 1902 and 1907, when pressure at Stykkisholm was in excess of the normal, thus intensifying the easterly current. The differences between the two groups are smaller in England than in Scotland, and the contrast is most pronounced in Scotland W. or the region nearest to the North Atlantic low pressure

area. It is of interest to note that the mean temperature of the Mays of 1900, 1904 and 1905 with pressure below normal in Iceland were warmer in Britain than those of 1899, 1902 and 1907 (Iceland pressure above normal) to the extent of 1°·4 in England, 1°·6 in Scotland, 1°·8 in Scotland W., 1°·5 in Scotland E., and 0°·9 in Scotland N.

AUSTRALIAN AND SOUTH AMERICAN CORRELATIONS.

During the three months January to March a remarkable parallelism is shown since 1897 in the curves of mean temperature at Alice Springs in the heart of Australia lat. 23° 38′ S., long. 133° 37′ E., height 1926 feet, and at Cordoba, Argentine Republic, lat. 31° 25′ S.,

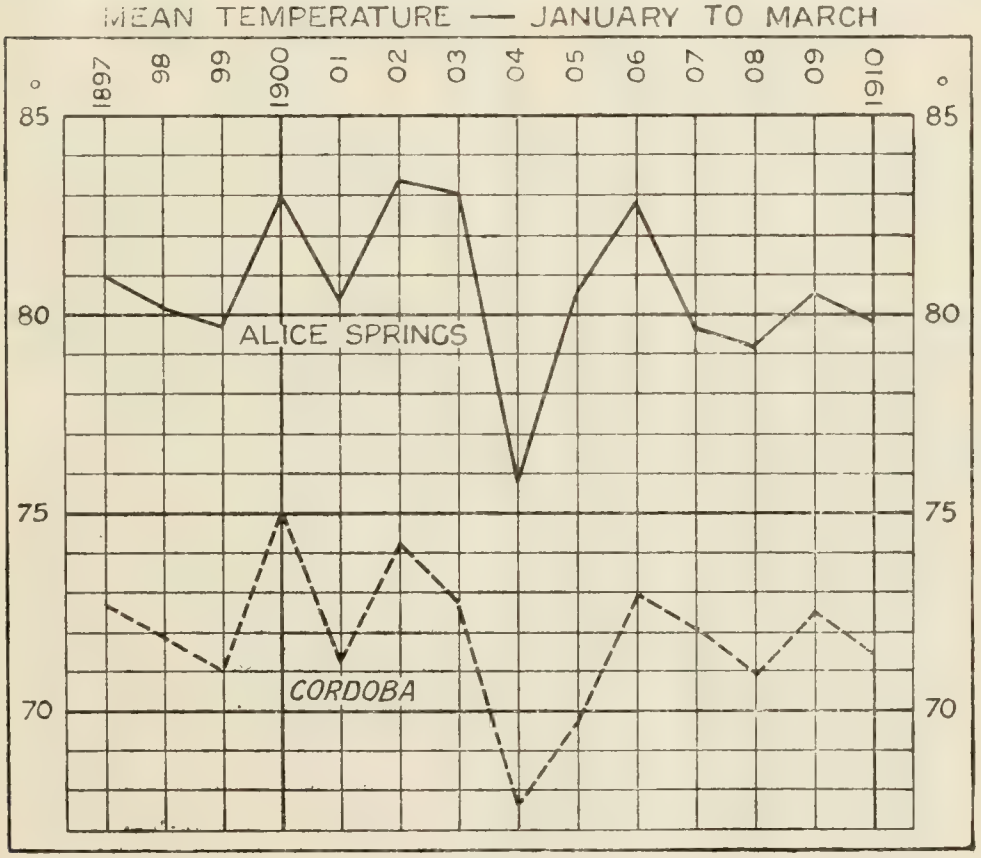

Fig. 3.

long. 64° 12′ W., height 1437 feet, both stations being located in a strictly continental situation.*

The following table gives the mean temperatures, the departure

* I am indebted to Mr. W. G. Davis, Director of the Argentine Meteorological Office for the Cordoba data, and to Mr. H. A. Hunt, Commonwealth Meteorologist for the Alice Springs values.

of these from the normal, and the year-to-year change for the period 1897-1910:—

Year.	Mean Temperature.*		Departure from Normal.		Year to Year Change.	
	Alice Springs.	Cordoba.	Alice Springs.	Cordoba.	Alice Springs.	Cordoba.
	°	°	°	°	°	°
1897	81·0	72·7	+0·4	+0·9	...	...
1898	80·2	71·9	—0·4	+0·1	—0·8	—0·8
1899	79·7	71·1	—0·9	—0·7	—0·5	—0·8
1900	83·0	75·0	+2·4	+3·2	+3·3	+3·9
1901	80·3	71·2	—0·3	—0·6	—2·7	—3·8
1902	83·3	74·2	+2·7	+2·4	+3·0	+3·0
1903	83·0	72·7	+2·4	+0·9	—0·3	—1·5
1904	75·7	67·6	—4·9	—5·2	—7·3	—5·1
1905	80·5	69·7	—0·1	—2·1	+4·8	+2·1
1906	82·8	72·9	+2·2	+1·1	+2·3	+3·2
1907	79·7	72·1	—0·9	+0·3	—3·1	—0·8
1908	79·2	70·9	—1·4	—0·9	—0·5	—1·2
1909	80·5	72·5	—0·1	+0·7	+1·3	+1·6
1910	79·8	71·4	—0·8	—0·4	—0·7	—1·1
Mean.....	80·6	71·8	...	...	±2·4	±2·2

Looking at the columns showing the departure from the normal it will be seen that the sign is the same in 11 of the 14 years discussed and the reverse in the other three. Further it will be observed that the very cold weather noted at Alice Springs in the year 1904 was also equally remarkable at Cordoba, while the years 1900, 1902, 1903, and 1906 notable for hot weather in the January to March period, were characterised by temperature excesses of much the same magnitude at both places, except in the year 1903 when the warmth was more pronounced in central Australia than in central Argentina. Previous to 1897 the records for the two places covering the 18 years 1879-1896 show no definite agreement.

The co-efficient of correlation is 0·89 and the probable error 0·12.

During the same three months of the year an opposition is shown in the mean temperature curves at Perth, West Australia, on the one hand and at Valparaiso and Santiago (Chile) on the other (see Fig. 4). At Perth and Valparaiso conditions are strictly insular, but at Santiago the conditions are those that pertain to an inland, but not a continental, situation as is the case at Alice Springs and Cordoba.

The following table shows the mean temperature of the January to March period for the three stations.

The mean values at Perth are the average of the daily maxima and minima, at Santiago the means are from hourly values and at Valparaiso from tri-daily readings brought to the mean of the 24 hours by corrections supplied by hourly term-day observations.†

* The mean at Alice Springs is the average of the maxima and minima. At Cordoba the data refer to hourly values.

† I am indebted to Mr. H. A. Hunt for the Perth data. The Santiago values are taken from the *Annuarios* of the Santiago Astronomical Observatory, and for Valparaiso from the annual publications of the Navy *(Servicio Meteorologico)*.

For the first two stations the data cover the 26 years 1886-1911, but for Valparaiso only the nine years 1901-1909 are available. The opposition, as in the case of the Cordoba-Alice Springs agreement, is not well marked previous to 1897, so that the data discussed refer to the same term of 14 years (1897-1910) as used for Alice Springs and Cordoba.

The mean temperatures are as follows :—

Mean Temperatures, January to March.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Perth	72·7	74·4	73·0	71·7	72·8	71·8	73·3
Santiago	65·7	64·3	64·8	65·0	65·8	67·6	65·6
Valparaiso	—	—	—	—	66·7	67·3	65·0

	1904.	1905.	1906.	1907.	1908.	1909.	1910.	Mean 1897-1910.
Perth	74·4	71·1	72·8	74·8	70·9	73·7	74·8	73·0
Santiago	64·8	65·6	66·8	65·2	67·1	65·6	64·3	64·9
Valparaiso	63·9	65·1	65·1	62·4	66·6	62·1	—	—

	Lat. S.	Long.	Height ft.
Perth	31° 57′	115° 52′ E.	49
Santiago	33° 27′	70° 42′ W.	1703
Valparaiso	33° 1′	71° 38′ W.	135

The following table shows the departure from the normal during the nine years 1901-1909 for which we have data from all three stations :—

	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
Perth	0°0	−1°0	+0°5	+1°6	−1°7	0°0	+2°0	−1°9	+0°9
Santiago....	−0·2	+1·6	−0·4	−1·2	−0·4	+0·8	−0·8	+1·1	−0·4
Valparaiso.	+1·8	+2·4	+0·1	−1·0	+0·2	+0·2	−2·5	+1·7	−2·8

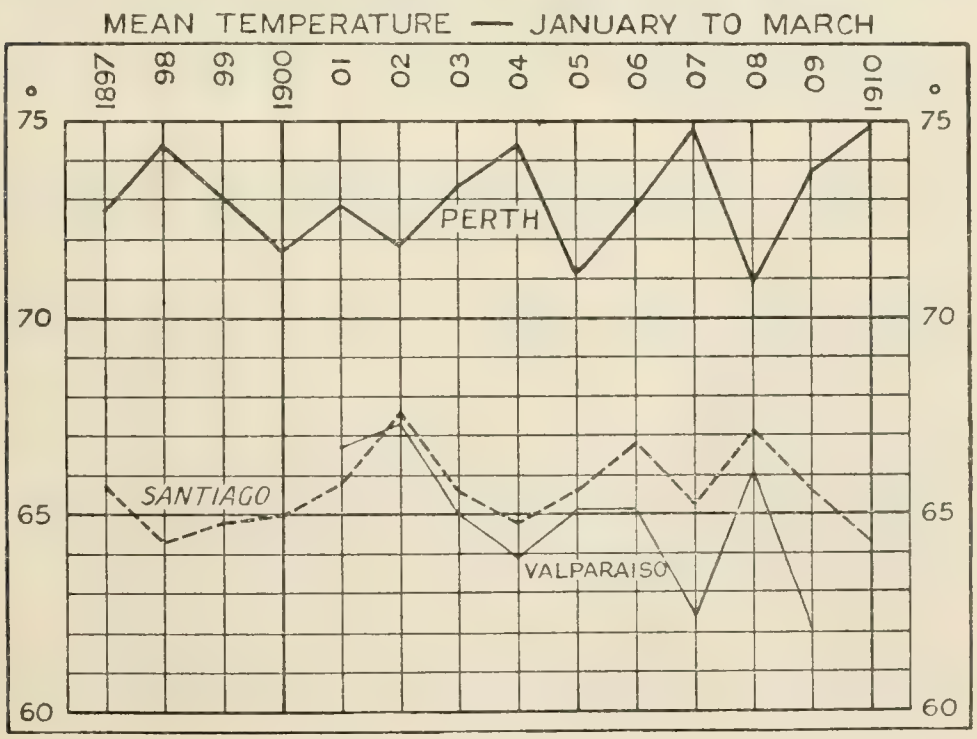

Fig. 4.

Referring the Perth and Santiago values to the mean of the 14 years 1897-1910 we find 11 cases in which the signs are the reverse of each other and 3 in which they agree. For the 11 years 1886 1896 in only 4 years is there an opposition, while in 7 years there is agreement, so that, as in the case of the Cordoba-Alice Springs observations, the correlation begins with the year 1897.

The co-efficient of correlation is 0·52, but the probable error is large, amounting to 0·22.

It is of interest to note that during the three months under review there is an opposition between the mean temperature at Santiago and the thickness of the ice at Duluth, Lake Superior, U.S.A.

The following are the values, those referring to Duluth being taken from the "Monthly Charts of the Great Lakes," issued by the U.S. Weather Bureau, and those for Santiago de Chile from the source already referred to :—

	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	Mean.
Ice at Duluth...	21·1	22·7	18·8	25·3	33·0	21·4	19·2	24·9	17·8	19·7	27·6	26·5	23·2 ins.
Santiago Temp..	65·0	65·8	67·6	65·6	64·8	65·6	66·8	65·2	67·1	65·6	64·3	64·0	65·6 deg.

Transforming the above values so as to show the departure from the normal of the 12 years under review we have the following :—

	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908	1909.	1910	1911.
Ice at Duluth ...	—2·1	—0·5	—4·4	+2·1	+9·8	—1·8	—4·0	+1·7	—5·4	—3·5	+4·4	+3·2 ins.
Santiago Temp.	0·6	+0·2	+2·0	0·0	—0·8	0·0	+1·2	—0·4	+1·5	0·0	—1·3	—1·6 deg

These results are of interest inasmuch as they indicate an inter-relation between the "action centres" governing the conditions during the three months under consideration in Australia, South America, and the United States.

RAINFALL AT MALDEN ISLAND AND MEAN TEMPERATURE AT PUNTA ARENAS FROM MAY TO AUGUST.

A relation can be traced between the amount of rain that falls at Malden Island,* South Pacific (lat. 3° 59′ S., long. 155° W.) during the period May to August, and the mean temperature at Punta Arenas* (lat. 53° 10′ S., long. 70° 54′ W.) during the same months. When the rainfall at Malden Island is above the average the temperature at Punta Arenas is below the normal and *vice versa.* The Malden Island data are wanting in August, 1894, May, 1897, June, 1898, and August, 1903, so that in the following totals the *mean* rainfall has been entered for the four missing months.

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* Rain data for Malden Island kindly supplied by Dr. W. N. Shaw, temperature data for Punta Arenas until 1907 taken from Marabini's paper "*Observatorio Meteorologico del Coleggio Salesiano 'S. Jose' en Punta Arenas de Magallanes.*" From 1908 to 1911 data are from this Observatory's Monthly Bulletins.

RAINFALL, MALDEN ISLAND, AND MEAN TEMPERATURE, PUNTA ARENAS, MAY TO AUGUST.

		1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
Rain.	Malden I.	2·8	3·5	6·7	4·2	(9·1)	2·0	6·4	(15·2)	(4·5)	10·7	16·0
Temp.	Punta Arenas.	37·5	36·6	37·7	38·6	38·0	38·0	38·6	35·4	38·1	36·3	34·2

		1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Rain.	Malden I.	2·2	15·3	7·1	7·8	33·3	9·4	6·8	1·6	6·7	2·5	4·2
Temp.	Punta Arenas.	37·8	35·5	37·2	35·6	33·8	33·6	35·6	36·1	34·3	36·3	37·5

Referring the above values to the normals for the whole period, viz. : 8·1 inches in the case of the Malden Island rainfall, and 36°·5 for the mean temperature at Punta Arenas, we get the following departures for the years under consideration : —

		1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
Rain.	Malden I.	—5·3	—4·6	—1·4	—3·9	+1·0	—6·1	—1·3	+7·1	—3·6	+2·6	+7·9
Temp.	Punta Arenas	+1·0	+0·1	+1·2	+2·1	+1·5	+1·5	+2·1	—1·1	+1·6	—0·2	—2·3

		1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
Rain.	Malden I.	—5·9	+7·2	—1·0	—0·3	+25·2	+1·3	—1·3	—4·5	—1·3	—5·6	—3·9
Temp.	Punta Arenas	+1·3	—1·0	+0·7	—0·9	—2·7	—2·9	—0·9	—0·4	—2·3	—0·2	+1·0

The correlation co-efficient deduced from the above data is 0·59, and the probable error 0·09.

During the first 17 years (1890-1906) there are only two years in

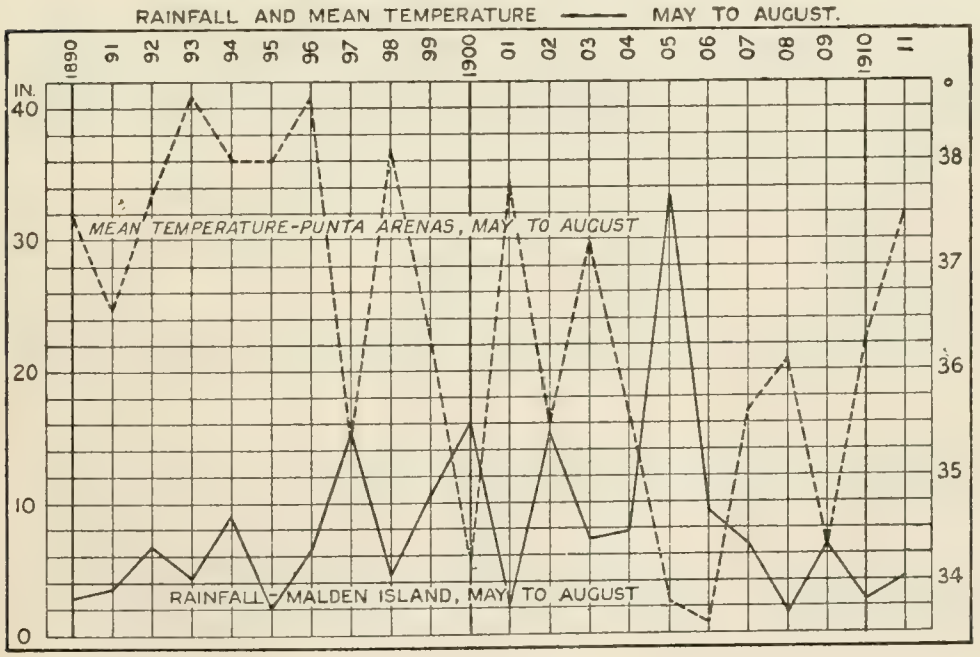

FIG. 5.

which the signs are the same, viz., 1894 and 1904, but in each of the four years 1907-1910 a low mean temperature at Punta Arenas was associated with a deficient rainfall at Malden Island during the

four months of the year under review. An examination of the data and diagrams given in Hildebrandsson's well-known papers shows occasional examples of an apparently well established correlation breaking down for a few years, and the specific case under discussion offers yet another instance of the snapping of the chain.

An examination of the wind direction at Evangelist's Island (lat. 52½° S., long. 75° W.), at the Pacific entrance to the Straits of Magellan, and situated at no great distance from Punta Arenas, shows that in months or seasons characterised by excessive precipitation at Malden Island the winds in the south of the South Pacific blow from the south and south-west, but during dry months or seasons at Malden Island the prevailing winds at Evangelist Island are from the west and north-west. In other words, during wet months at Malden Island barometic pressure in the Antarctic regions south of Cape Horn is relatively high, and in dry years lower than usual, causing in the latter instance west and north-west winds to blow with increased frequency at Evangelist's Island. At the same time the South Pacific anti-cyclone is not only more intense but is lying further south than usual, and this, doubtless, causes some change in the position of the eastern margin of the equatorial South Pacific low pressure belt (see Isobaric Maps from May to August given in Dr. Buchan's *Challenger* Report on *Atmospheric Circulation*) so that rain-bearing winds at Malden Island blow with considerably diminished frequency. Hildebrandsson has shown that the variations of barometric pressure and rainfall between Tahita and Tierra del Fuego are in opposite directions so that this opposition between the Malden Island rainfall and the temperature at Punta Arenas is probably brought about by the same physical processes induced by changes in the position of the South Pacific " action centres."

AJO, GENERAL LAVALLE, BUENOS AIRES, AND TRINIDAD, WEST INDIES.

A pronounced feature of many correlations is their temporary character, this applying more particularly to pairs of stations not located in action centres, but situated in intermediate zones, where correlations are set up without any apparent reason, persist with varying degrees of intensity for fluctuating periods, and disappear with the same abruptness that initiated their commencement. An interesting example of this nature is shown by a comparison of the April to September rainfall at Trinidad, West Indies (lat. 10° 40′ N., long. 61° 31′ W.), and the rainfall at Ajo, Argentine Republic (lat. 36° 31′ S., long. 56° 46′ W.) for the six months following.

The data referring to Trinidad are based on a table of monthly

and annual rainfall from 1862 to 1910,* kept at the Royal Botanic Gardens, which was included among a large mass of valuable printed data referring to British Colonial stations, recently received from the London Meteorological Office. The data from Ajo are from a manuscript record kept at Estancia Linconia kindly furnished by Mr. Herbert Gibson. The observations, which are still continued, cover the period, 1858—1911, thus embracing 54 years (see Table II.) The values up to the year 1884 have already appeared in a paper,† published a quarter of a century ago, from the pen of the late Mr. Thomas Gibson, who initiated the observations.

Whatever may be the causes that determine the general character of the rainy season at Trinidad, *i.e.*, whether the rain will be above or below the normal, the character of the season is usually impressed on the records as early as April and May. If we take the combined rainfall of these two months for the 50 years, 1862—1911, and compare the values with those of the four months following, we find 36 years in which the deviation from the normal was represented by the same sign as the corresponding June to September values, and 14 cases in which they differed. In the 19 years, 1876—1894, during which the pronounced opposition with Ajo prevailed, there is only one year (1878) in which the April and May rainfall at Trinidad was not a direct index of that of the four succeeding months.

Of the fourteen cases of non-agreement, ten occurred in the period during which the negative correlation of the April to September rainfall with that at Ajo during the next six months was not marked.

An examination of the rainfall for April and May for the fourteen cases in which the following June to September rains were not in agreement with those of the two months under consideration, shows ten cases in which the rains in the earlier period were below the average and only four in which they were above the average. In other words if the April and May rainfall at Trinidad is *below* the average the period June to September following has also a rainfall below the normal in 66 per cent. of the cases. On the other hand, if the April and May rains are *above* the normal, then the probability of agreement in the four succeeding months rises to 81 per cent.

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* I am obliged to Mr. W. G. Freeman, B.Sc., Government Botanist of the St. Clair Experiment Station, Trinidad, for the monthly rainfall there during the years 1911 and 1912. The data are as follows :—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1911 ...	1·61	1·51	1·86	·74	1·27	7·15	4·73	13·68	4·03	10·22	3·57	3·53	53·90
1912 ...	·62	·20	·74	·03	2·18	7·54	12·16	5·56	5·58	2·73	6·28	5·64	49·26

† *Jour. Scot. Met. Soc.*, 3rd Series, Vol. 7, p. 192.

TABLE II.—*Rainfall at Estancia Linconia, Ajo, Province of Buenos Aires.*

Lat. 36° 31′ S. Long. 56° 46′ W. Distance from sea 12 miles. Gauge 5 feet above ground.

	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	YEAR.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1858...	2·39	2·00	3·26	1·01	8·22	2·49	1·47	2·07	7·25	4·22	3·62	2·37	40·37
1859...	·72	1·22	2·00	1·77	3·91	1·24	2·45	1·93	2·57	1·86	3·27	·49	23·43
1860...	·86	5·48	6·74	2·01	6·85	6·20	2·97	2·96	1·34	4·83	2·31	·81	43·36
1861...	·07	3·00	1·15	5·40	·87	·55	·29	3·26	1·10	3·09	·59*	·62	19·99*
1862...	1·18	·64	4·75	1·00	5·67	**8·32**	2·93	·62	1·09	1·20	3·55	2·59	33·54
1863...	4·04	1·19	1·81	1·10	1·52	5·20	·70	·32	2·56	3·15	1·89	2·27	25·75
1864...	1·54	1·94	·54	6·60	3·85	5·61	2·13	3·71	2·59	3·26	1·80	**6·78**	40·35
1865 ..	5·61	2·93	3·42	3·26	3·38	5·42	2·33	2·17	2·26	3·75	1·37	1·63	37·53
1866...	·25	·96	1·55	2·21	6·69	1·77	2·93	3·09	1·97	3·88	2·96	1·52	29·78
1867...	·82	·75	2·00	3·69	2·62	1·05	2·33	2·12	·45	·70	4·17	2·22	22·92
1868...	4·46	1·94	7 65	·20*	·44	3·20	·46	2·05	4·47	4·32	3·19	2·80	35·18
1869...	7·12	2·63	2·69	3·03	·25	·00*	·76	·00*	4·33	2·00	5·07	4·97	32·85
1870...	2·05	4·28	3·60	3·29	3·84	·57	1·32	·25	·00*	2·54	5·24	·56	27·54
1871...	2·10	**7·46**	7·11	2·41	·74	6·10	·00*	1·70	1·12	2·48	1·48	4·46	37·16
1872...	6·16	2·60	3·15	1·92	1·82	3·37	1·84	5·32	·87	1·12	3·15	3·56	34·88
1873...	4·86	4·47	·00*	2·80	·88	1·83	·00*	2·65	2·29	2·26	3·15	2·07	27·26
1874...	1·49	2·65	2·00	1·20	5·03	1·82	2·96	5·10	4·08	4·77	3·76	·75	35·61
1875 ..	3·94	2·10	·50	5·11	2·55	·47	2·10	1·07	1·04	1·96	·86	1·32	23·02
1876...	2·64	3·42	5·35	4·61	2·90	3·62	2·82	3·46	·57	3·18	2·06	1·79	36·42
1877...	·00*	1·60	5·78	3·37	5·82	2·59	**6·52**	2·97	·85	3·33	2·01	4·29	39·13
1878...	4·32	·55	4·23	5·10	2·30	4·42	1·28	1·11	·70	3·80	3·37	3·30	34·48
1879...	1·38	2·42	5·80	·68	4·25	6·12	2·08	·75	1·25	1·00	2·62	·86	29·21
1880...	5·88	2·28	3·57	·59	1·99	4·03	1·80	1·22	1·48	1·83	4·39	3·56	32·62
1881...	2·92	1·48	1·27	2·33	·57	4·85	2·64	1·61	6·92	5·20	2·03	1·20	33·02
1882...	2·67	1·33	2·02	2·15	·87	1·19	1·13	4·65	1·28	2·45	1·63	1·52	22·89
1883...	3·96	·35*	7·92	1·78	2·67	5·07	4·15	2·14	2·24	3·42	2·95	1·45	38·10
1884...	1·18	·77	2·37	5·52	·25	2·37	·65	2·12	**12·64**	3·02	1·49	2·15	34·53
1885...	3·02	6·40	7·41	3·00	3·00	2·34	1·82	1·69	2·13	4·15	2·90	6·44	44·30
1886...	3·56	·67	6·19	2·94	1·71	2·62	·35	·54	3·05	3·90	·95	3·40	29·88
1887...	1·10	4·18	1·45	2·72	·00*	6·95	1·05	2·88	1·60	3·39	2·02	4·63	31·97

TABLE II.—*Rainfall at Estancia Linconia, Ajo, Province of Buenos Aires—(continued).*

	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	YEAR.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1888...	4·42	2·27	3·50	5·32	·36	2·54	5·47	3·50	2·76	2·67	1·54	4·53	38·88
1889 ..	**12·30**	2·59	3·09	3·33	2·43	2·76	3·32	3·88	1·47	·40*	3·09	1·49	40·15
1890...	1·99	2·25	4·02	3·24	1·75	2·20	4·52	2·57	·95	1·13	1·38	2·43	28·43
1891...	2·59	3·39	2·95	·54	3·97	1·24	3·11	4·47	·26	4·77	2·73	4·57	34·59
1892..	1·90	1·59	3·67	·72	2·92	·12	2·57	2·50	5·33	4·74	1·61	1·71	29·38
1893...	2·53	·50	2·96	3·28	·66	·89	3·64	1·67	·33	1·54	2·66	·54	21·20
1894...	3·05	1·75	·97	·22	1·59	·80	1·50	3·43	2·35	6·62	3·67	2·92	28·87
1895...	3·34	2·09	10·91	1·95	·55	1·89	2·48	3·01	3·64	1·40	4·15	4·38	39·79
1896...	2·04	1·49	1·47	2·61	·83	·82	5·59	2·48	4·98	2·77	3·20	·47*	28·75
1897...	·93	2·74	3·37	1·00	3·06	2·28	1·13	·59	3·46	2·45	3·45	2·90	27·36
1898...	4·15	2·03	5·57	3·55	3·33	5·94	1·31	2·37	4·16	2·71	1·71	1·62	38·45
1899...	2·31	3·53	4·51	4·92	5·39	1·85	6·47	**10·21**	·54	2·62	3·39	5·18	50·92
1900...	2·43	3·89	**15·88**	·79	5·21	3·40	5·87	5·57	6·28	3·96	**5·26**	1·24	**59·78**
1901...	2·21	2·71	2·02	3·07	**9·67**	1·28	·50	3·78	1·48	2·12	3·48	2·32	34·64
1902...	3·05	1·38	4·33	2·36	3·72	1·10	1·32	1·14	2·49	·93	1·63	2·93	26·38
1903...	2·94	2·42	4·11	3·21	2·20	5·24	1·81	3·92	2·47	1·46	2·59	4·99	37·36
1904...	4·24	6·16	5·08	4·76	·45	1·97	3·90	5·18	·89	5·61	2·28	·53	41·05
1905...	1·54	2·24	2·07	4·17	1·63	3·46	1·99	·00*	2·22	**6·98**	1·34	4·30	31·94
1906...	·81	1·91	2·26	6·10	3·54	2·46	3·70	3·68	6·70	3·65	1·91	2·94	39·66
1907...	1·09	·40	8·87	6·69	·00*	2·91	2·76	4·11	2·07	3·32	·77	1·99	34·98
1908...	1·47	1·65	2·53	**6·90**	1·06	2·68	1·29	1·87	·59	2·03	4·28	1·52	27·87
1909...	4·74	2·42	·73	1·18	·22	2·88	3·52	3·14	4·83	2·59	3·09	2·97	32·31
1910..	2·93	2·18	3·02	·75	·39	2·03	2·00	3·11	1·46	1·74	2·06	·68	22·35
1911...	6·62	3·65	·24	2·57	6·22	·65	2·39	1·28	·98	4·20	1·78	6·77	37·35
Mean ...	2·93	2·42	3·80	2·89	2·72	2·87	2·38	2·63	2·57	3·01	2·65	2·64	33·51
1912...	5·10	2·17	6·93	2·99	3·47	3·97	1·42	2·15	1·66	3·80	5·89	1·29	40·84
1913 ..	·07	1·97	8·46	—	—	—	—	—	—	—	—	—	—

Dealing with the 50 years, 1862 to 1911, common to both series of observations (see Table III.) we find that from 1862 to 1877, and from 1895 to 1911, there was no relation between the rainfall at Trinidad from April to September and that at Azo during the six months following. On the other hand during the 17 years, 1878 to 1894, the two curves are the reverse of each other. These results apply to the values referred to the 50 years' means, which are 40·47 in. for Trinidad, and 17·85 in. at Ajo.

TABLE III.—*Rainfall at Trinidad (Lat. 10° 40′ N., Long. 61° 31′ W.) and Ajo (Lat. 36° 31′ S., Long. 56° 46′ W.)*

Year.	Trinidad. April to September.	Ajo. Oct. to March following.	Departure from Normal. Trinidad.	Ajo.	Year.	Trinidad. April to September.	Ajo. Oct. to March following.	Departure. from Normal. Trinidad.	Ajo.
	in.	in.	°/₀	°/₀		in.	in.	°/₀	°/₀
1862	42·03	14·38	+ 4	—19	1889	46·68	13·24	+15	—26
1863	43·99	11·33	+ 9	—36	1890	50·35	13·87	+24	—22
1864	40·42	23·80	0	+34	1891	33·10	19·23	—18	+ 8
1865	49·36	9·51	+22	—47	1892	63·73	14·05	+57	—21
1866	35·17	11·93	—13	—31	1893	66·48	10·51	+64	—41
1867	46·81	21·14	+16	+19	1894	29·24	29·55	—28	+66
1868	36·13	22·75	—11	+28	1895	22·75	14·93	—44	—16
1869	34·39	21·97	—15	+23	1896	34·71	13·48	—14	—24
1870	46·51	25·01	+15	+40	1897	48·64	20·55	+20	+15
1871	46·30	20·33	+14	+14	1898	42·67	16·39	+ 5	— 8
1872	29·96	17·16	—26	— 4	1899	23·97	33·39	—41	+86
1873	24·05	13·62	—41	—24	1900	45·77	17·40	+13	— 2
1874	52·81	15·82	+30	—12	1901	36·18	16·68	—11	— 6
1875	38·97	15·55	— 4	—13	1902	38·06	14·96	— 6	—16
1876	58·93	14·41	+45	—19	1903	38·80	24·52	— 4	+37
1877	42·68	18·73	+ 5	+ 5	1904	33·05	14·27	—18	—20
1878	39·44	20·07	— 3	+13	1905	43·15	17·60	+ 7	— 1
1879	44·39	16·21	+10	— 9	1906	44·88	18·86	+11	+ 6
1880	45·21	15·45	+12	—13	1907	40·23	11·73	— 1	—34
1881	46·62	14·45	+15	—19	1908	30·53	15·72	—25	—12
1882	30·90	17·83	—24	0	1909	37·92	16·78	— 6	— 6
1883	49·62	12·04	+22	—32	1910	39·67	14·99	— 2	—16
1884	30·70	23·49	—24	+32	1911	31·60	26·95	—22	+51
1885	25·65	23·91	—37	+34					
1886	50·38	14·98	+25	—16	Mean	40·47	17·85	...	...
1887	32·97	20·23	—19	+14					
1888	37·10	26·72	— 8	+50	1912	33·05	21·48	—18	+21

On referring the values to the means of the 19 years, 1876 to 1894, viz., 43·38 in. at Trinidad, and 17·84 in. for Ajo, we get an uninterrupted correlation, as will be apparent from the following values showing the percentage of excess or defect referred to the above short average. Under the first year, 1876, is entered the value at Trinidad for April to September of that year, and at Ajo for the six months following, *i.e.*, from October, 1876, to March, 1877, and so on.

	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885
Trinidad % ...	+36	—2	— 9	+2	+ 4	+ 7	—29	+14	—29	—41
Ajo %	—19	+5	+13	—9	—13	—19	0	—32	+32	+34

	1886	1887	1888	1889	1890	1891	1892	1893	1894
Trinidad %	+16	—24	—14	+ 8	+16	— 34	+47	+53	—33
Ajo %	—16	+14	+50	—26	—22	+ 8	—21	—41	+66

The correlation co-efficient deduced from the above values reaches the high value of 0·79, with probable error of 0·06. The following diagram shows the data in graphic form.

RAINFALL DEPARTURE FROM NORMAL, 1876-1894, AT TRINIDAD, WEST INDIES, AND AJO, ARGENTINE.

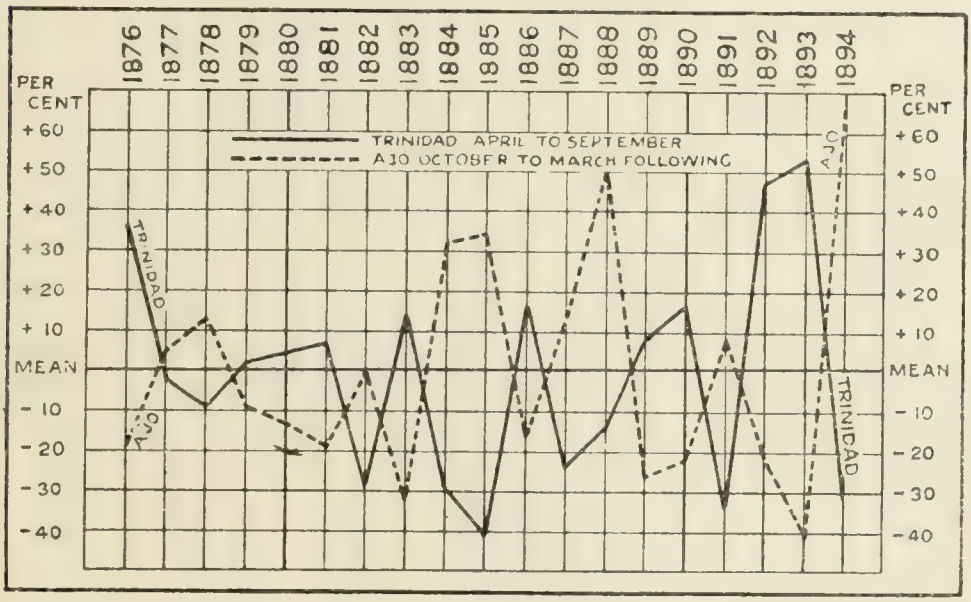

Fig. 6.

These results are of considerable interest as they show that the physical processes that produced a given precipitation at Trinidad, 11° N. of the equator, during the period under discussion, were associated during the six months following by an opposite effect at Ajo in the south temperate zone, some 2,850 geographical miles distant. The effect so far as shown by available material, which embraces five stations in the Argentine Republic* and two in Brazil, is greatest on the Atlantic seaboard, with a hypothetical maximum out in the ocean some distance to the east of Ajo. At Buenos Aires the co-efficient has fallen to — ·47, and two stations to the north, situated respectively 190 and 310 miles distant from that city, give values of —·40 and —·52, with probable errors of ·11 and ·13 respectively, that of Buenos Aires being ·12. To the west the relation dies out completely as Cordoba shows a positive correlation of ·17. At Rio de Janeiro (lat. 22° 54′ S.) there is a value of —·10, and at Alto da Serra (lat. 23° 40 S., height 2,625 feet), —·38. Had a large number of stations been available for comparison with

* I am indebted to Mr. W. G. Davis, Director, for permission to examine the Argentine data.

Trinidad during the 19 years under review it would have been possible to draw, what may in this case be termed *post iso-cohyetal lines*, or lines drawn through points having the same correlation co-efficient. In this way some clue to the precise mechanism governing this correlation might be obtained, since the boundaries of the area covered by the rainfall inversion would be clearly defined for the land regions of the south temperate zone. As regards the equatorial and tropical regions it would be desirable to utilise data from other stations north and south of the equator which would indicate the area around Trinidad, or perhaps some more potent centre involved in the correlation. An analysis of the winds at littoral stations on the coast of South America from 38° S. to N. of the equator would also help to throw light over the problem in hand.

An attempt to trace a relation between the April to September rainfall at Trinidad and that of the six months following at some places in Europe, the United States, and other regions has failed, but one or two interesting correlations have shown up which may now be disposed of.

It was noted that the rainfall of Java* for the six months, October to March, was in general the reverse of that at Trinidad during the six months following, the correlation co-efficient for the 30 years 1880-1909 was ·47 and probable error ·11, and during the 18 years 1883-1900, when the variation was more pronounced, as high as ·57 with probable error ·11. During these 18 years the October to March rainfall at Ajo agreed in the main with that recorded at Java for the same period of the *previous* year, the result showing a correlation of +·44 and a probable error of ·13.† It was further observed that the January to March rainfall at Baltimore, U.S.A.,‡ and at San Fernando, near Cadiz,§ on the coast of Spain, for the same months during the period 1851-1880 were in general the reverse of each other, the correlation co-efficient being –·57 and probable error ·05. After 1880 until 1904, the last year utilized, there is no agreement, so that the correlation co-efficient for the whole period of 54 years falls to ·21. It is of interest to note that the opposition between the rainfall of Stykkisholm and Brussels discovered by Hann, which was well marked during the 21 years 1857-1878, diminished later and completely disappeared in 1900.‖ From which it may be inferred that the physical processes at work involved both the Stykkisholm—Brussels, and the Baltimore—Cadiz correlations, since a diminution of intensity was noted about the same time, viz. 1880.

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* Data from *Regenwaarnemingen in Nederlandsch-Indie*, 1905. Table XV. pp. 510-11. From 1906 to 1909 values computed from data given in subsequent annual volumes.

† For precise value to be assigned to these figures see *Forecasting Weather*, by Dr. W. N. Shaw, F.R.S., p. 362.

‡ Data from Maryland Weather Service, *Climate of Baltimore*, Vol. 2, pp. 186-187.

§ Data from *Schwankungen der Niederschlage.* Von G. Hellmann, Berlin, 1909, p. 1.

‖ See Hildebrandsson's fourth paper on "*Centres d'Action de l'Atmosphére,*" p. 21.

CORRELATIONS AT ST. HELENA.

Although St. Helena is not located in an "action centre," the observations from this island are of considerable interest, inasmuch as they are influenced by and are an index of the intensity of the S.E. Trades. Although considerable time and labour have been expended in a search for correlations between St. Helena and places in the two hemispheres, the results so far cannot be looked upon as conclusive, owing to the relatively short period covered by the St. Helena record. Some suggestive resemblances and contrasts have however shown up, which will be briefly referred to.

During the 11 years 1893 to 1903 there was an undoubted relation between the quantity of rainfall over a wet district in the vicinity of Fort William during the period, January to March, and the mean temperature at St. Helena for the four months, May to August,

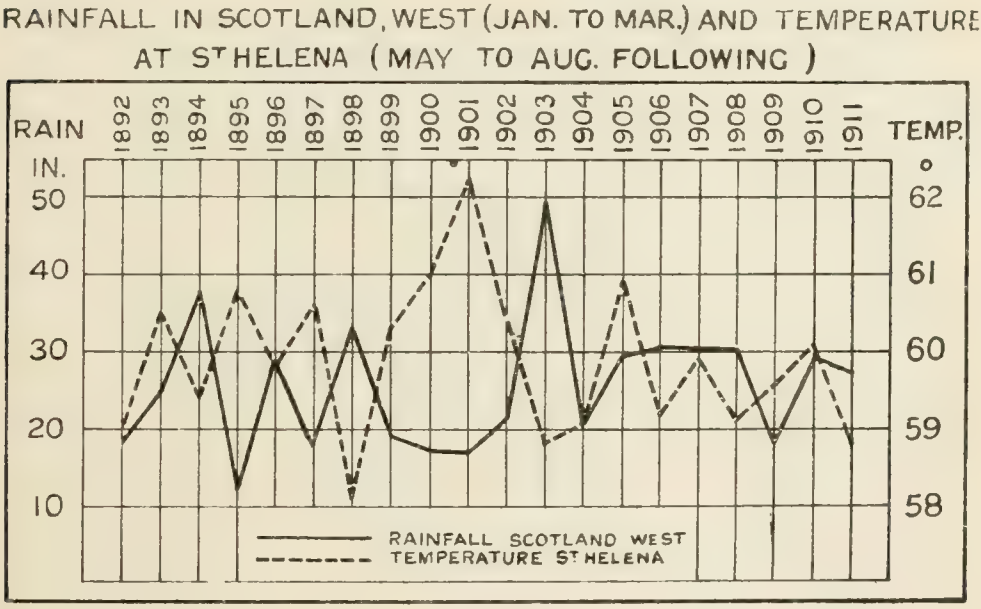

Fig. 7.

following. The district rainfall mean for Scotland west is the average of the five stations, Glenquoich, Invergarry, Bendamph, Glencarron and Fort William, the data being extracted from the *Journals of the Scot. Met. Soc.*, while the St. Helena mean temperature is from the publication *M.O.* 203, supplemented by later data kindly forwarded by Dr. Shaw.

From 1904 to 1911 the correlation breaks down, both the rainfall and the temperature data showing little fluctuation from one year to another as compared with the 11 years preceding.

Rainfall, Scotland West, January to March, and Mean Temperature St. Helena, May to August following.

	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
RAIN, Scotland W., Jan. to March	18·4	24·9	37·8	12·4	29·6	18·4	33·5	19·6	17·4	16·9
TEMP., St. Helena May to Aug. following	59·0	60·5	59·4	60·8	59·8	60·6	58·1	60·3	61·0	62·2

	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	Mean.
RAIN	21·7	49·3	20·5	29·8	30·9	30·5	30·2	18·6	29·1	27·5	25·8 in.
TEMP.....	60·4	58·8	59·1	60·9	59·2	59·9	59·1	59·6	60·1	58·8	59·9 deg.

Departure from Normal.

	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
RAIN, Scotland W. ..	—7·4	—·9	+12·0	—13·4	+3·8	—7·4	+7·7	—6·2	—8·4	—8·9
TEMP., St. Helena ...	— ·9	+ ·6	— ·5	+ ·9	— ·1	+ ·7	—1·8	+ ·4	+1·1	+2·3

	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
RAIN	—4·1	+23·5	—5·3	+4·0	+5·1	+4·7	+4·4	—7·2	+3·3	+1·7 in.
TEMP.....	+ ·5	— 1·1	— ·8	+1·0	— ·7	·0	— ·8	— ·3	+ ·2	—1·1 deg.

The data discussed are for the 20 years, 1892 to 1911, and are given in the preceding table, the actual values being shown in Fig. 7.

The co-efficient of correlation is 0·55, and probable error 0·15.

A relation can be traced between the mean temperature at St. Helena during the four months, January to April, and the mean

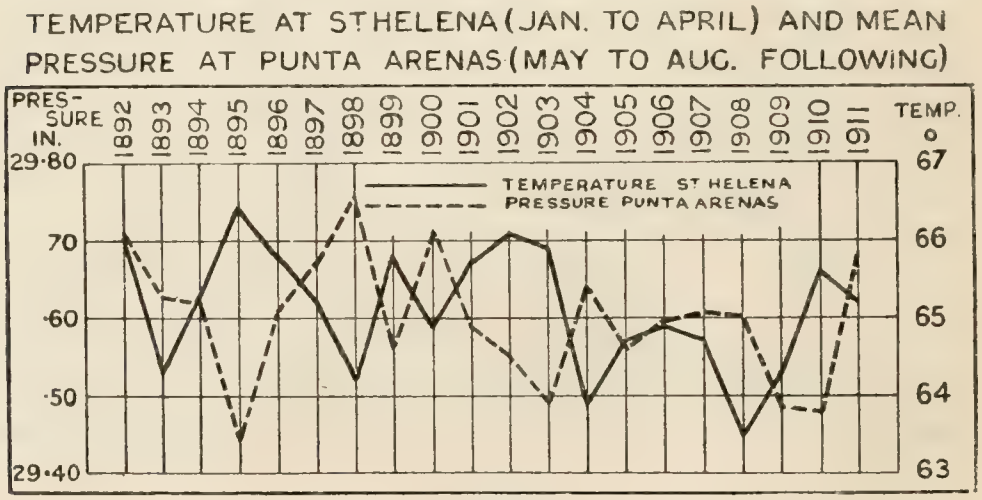

Fig 8.

barometric pressure at Punta Arenas, in Magellan Straits, during the four months following. This relation is shown by the circumstance that if the January to April temperature at St. Helena shows a rise as compared with the year previous, the pressure at Punta Arenas during the period, May to August, in general shows a fall, and *vice versa*. During the last six years, 1906 to 1911, of the period discussed the results are not very conclusive, this being probably due to the position occupied by Punta Arenas, which is in some groups

of years dominated by Atlantic and in other periods by Pacific influences. The mean temperature and pressure values are as follows :—

	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
TEMP., St. Helena, Jan. to April	66·0	64·3	65·3	66·4	65·8	65·2	64·2	65·8	64·9	65·7
PRESSURE, Punta Arenas, May to August ... 29 in.+	·71	·63	·62	·44	·61	·67	·76	·56	·71	·59

	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	Mean.
TEMP.	66·1	65·9	63·9	64·7	64·9	64·7	63·5	64·3	65·6	65·2	65·1 deg.
PRESSURE...	·55	·49	·64	·56	·60	·61	·60	·49	·48	·68	29·60 in.

Fig. 8 shows the above data in graphic form.

Too much weight cannot be attached to this correlation, since for the whole period the co-efficient is only 0·35, with a large probable error 0·21. Still the results up to the year 1904 suggest that a relation does prevail at times between the two places.

The majority of correlations which break down do so completely, passing into an indefinite type, in which the characteristic phases of

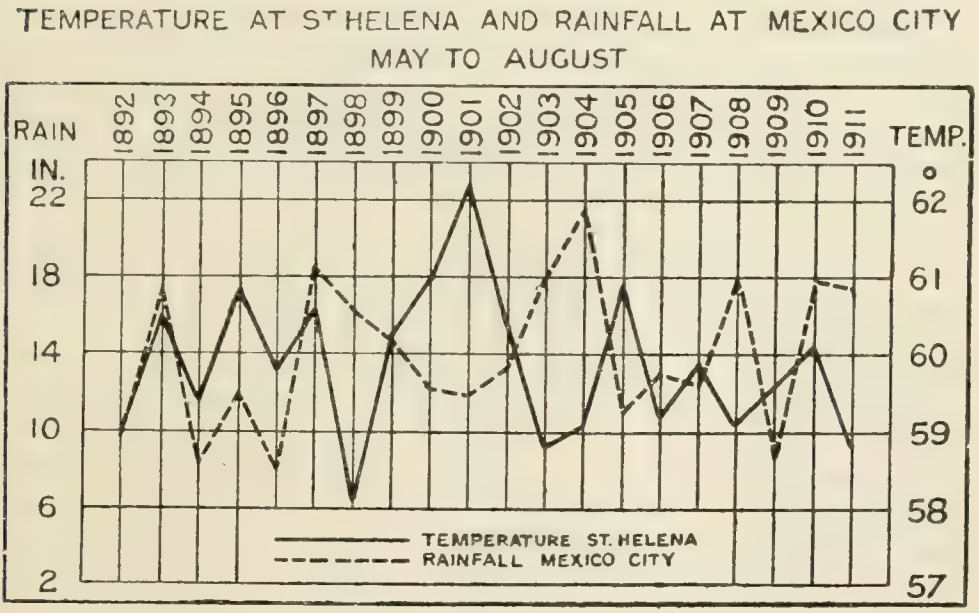

Fig. 9.

the curves are sporadically mixed up with cases of complete disagreement. Sometimes, however, a correlation which for some years may be of a positive nature, changes suddenly into one of a negative character, which may persist for some years. An example of this is shown by a comparison of the May to August rainfall at Valle de Mexico, lat. 19° 26′ N., long. 99° 08′ W., height 7,480 feet, with the mean St. Helena temperature for the same months. The St. Helena values have already appeared in this article, those referring to the

Mexico rainfall (extracted from the monthly bulletins of the Central Observatory) being as follows, in inches :—

1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
9·7	17·3	8·3	13·0	8·1	18·6	15·4	14·6	12·2	12·0
1902	**1903**	**1904**	**1905**	**1906**	**1907**	**1908**	**1909**	**1910**	**1911**
13·4	18·0	21·6	11·2	13·1	12·5	17·9	8·7	17·8	17·6

In this case we find the two curves (see Fig. 9) pursuing the same course from 1892 to 1898, while from 1899 to 1909 they were the reverse of each other, coming into agreement again in 1910 and 1911.

Somewhat similar results are shown from a comparison of the January barometric pressure curves at Ponta Delgado, Azores, and Punta Arenas during the 24 years, 1889—1912. For the 13 years, 1892—1904, the departures from the normal for the two places were the opposite in 11 years and the same in two years, while in the five years succeeding (1905 to 1909), the departures from the normal were positive at both places.

CORRELATIONS IN SOUTH AMERICA.

Hildebrandsson has shown in his third memoir, p. 9, that the temperature variations in winter (January and February) are the same over a wide area extending from the Faeröe to Western Siberia, the six stations discussed ranging in latitude from 59° to 64½° N. In the Argentine Republic and Chile, between the parallels, of 29° and 35° S., and the meridians of 58° and 69° W., the winter variations of temperature at four selected stations, where long records are available, are in harmony with each other for the period May to August. On extending the area of inquiry into Brazil, it was found that the winter temperature at Rio de Janeiro (lat. 23° S., long. 44° W.) was usually not in agreement with the conditions in the south.

In the following table the departure from the normal of the 36 years, 1876-1911, is given for the five stations under discussion, the actual mean temperature being shown graphically in Fig. 10. For the Argentine data we are indebted to Mr. W. G. Davis, Director of the Argentine Meteorological Office ; the values for Rio de Janeiro are from Señor Crul's well-known work, supplemented by data since 1890 sent by Dr. Morize ; while the Santiago data are from the official publications of that Observatory. The data are strictly comparable since they refer to hourly values in each instance.

Mean Temperature, May to August. Departure from Normal, 1876 to 1911.

	1876	1877	1878	1879	1880	1881	1882	1883	1884
Santiago de Chile..	+°·3	+1°·8	+°·7	+°·7	+1°·3	—°·4	—°·2	—1°·1	—1°·3
Cordoba	+ ·3	— ·8	—1·3	— ·3	+1·6	—1·7	·0	+ ·3	·0
Buenos Aires	+2·1	+1·3	—1·5	+ ·3	+1·3	— ·4	— ·6	+ ·4	—1·3
Goya	+3·5	+2·3	— ·3	+ ·7	+1·0	—1·2	— ·8	—1·0	— ·5
Rio de Janeiro.....	+ ·3	+2·5	+2·2	—1·3	+3·3	·0	—1·1	— ·5	+ ·4

Mean Temperature, May to August. Departure from Normal, 1876 to 1911 (continued).

	1885	1886	1887	1888	1889	1890	1891	1892	1893
Santiago de Chile..	—1·6	—1·1	+ ·8	— ·1	—1·3	—2·0	+1·3	—2·3	—1·9
Cordoba	—2·5	— ·2	+3·0	+ ·3	—1·5	—1·1	— ·4	— ·9	—1·6
Buenos Aires	—2·8	—1·0	+1·3	— ·2	— ·8	—1·9	·0	—1·3	—1·6
Goya	—3·8	—2·4	+ ·8	—1·2	—1·7	—3·0	— ·2	—3·0	—2·2
Rio de Janeiro ...	+1·6	—2·4	+ ·2	— ·2	+ ·6	— ·6	— ·4	—1·7	—1·9

	1894	1895	1896	1897	1898	1899	1900	1901	1902
Santiago de Chile..	— ·4	+ ·9	+3·9	+ ·6	— ·5	+1·1	+1·3	+1·0	·0
Cordoba	— ·4	+3·1	+3·8	—1·2	— ·3	+3·1	+1·9	+2·9	+ ·4
Buenos Aires	—1·5	+2·2	+2·4	— ·8	—1·6	+2·4	+2·1	+2·0	+1·1
Goya...	—1·1	+2·0	+2·8	—1·3	— ·8	+3·1	+3·8	+2·3	+1·7
Rio de Janeiro.....	—1·5	— ·2	—1·0	—1·2	+ ·3	+ ·5	— ·4	— ·3	+1·4

	1903	1904	1905	1906	1907	1908	1909	1910	1911	Mean.
Santiago ...	— ·8	+2·3	+2·1	— ·4	— ·1	+ ·3	— ·4	—1·9	—1·0	48·0
Cordoba ...	— ·3	+1·0	— ·2	— ·6	—2·8	+ ·1	—1·2	— ·3	—1·1	52·5
Buenos Aires	+1·8	+1·9	+ ·3	+ ·7	—1·7	— ·3	— ·7	— ·5	—1·5	52·1
Goya	+1·3	+ ·6	+1·4	+1·1	— ·3	— ·2	— ·4	+ ·9	—2·2	59·2
Rio Janeiro	+ ·2	—1·2	+1·4	+2·7	— ·4	+1·0	+ ·1	+ ·1	—1·3	69·3

Taking Cordoba as the station of comparison Santiago shows a co-efficient of correlation of 0·60, and a probable error 0·14, while the values for Buenos Aires are 0·79 and 0·10, and for Goya 0·68 and 0·12.

TEMPERATURE AT SOUTH AMERICAN STATIONS FROM MAY TO AUGUST, 1876-1911.

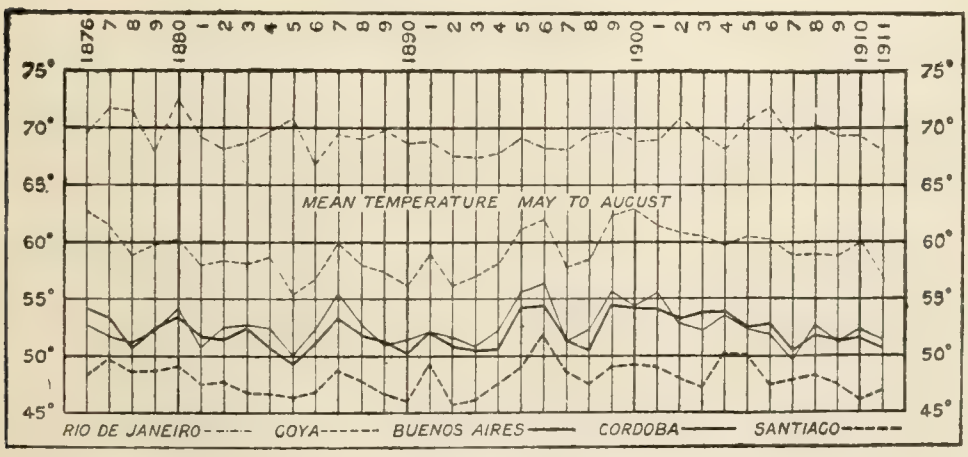

FIG. 10.

Excluding the Brazilian station, it will be seen that in two-thirds of the years discussed the departures from the normal were represented by the same sign at all the stations, although the Andine

chain separates Santiago de Chile on the west side of the range from the Argentine stations on the east side. Taking cases in which the temperature departures at the latter stations were all of the same sign, there were only three seasons, viz., those of 1878, 1891 and 1897 in which Santiago differed as regards sign. During the above winters the weather was warm on the west side and cold on the east side of the Andes.

The warmest winter was that of 1896 at Santiago, Cordoba and Buenos Aires, and at Goya the temperature was also much above the normal, but at this station the maximum May to August temperature was in 1900.

The coldest winter occurred at Goya and Buenos Aires in 1885, at Cordoba in 1907, and at Santiago in 1892. On the mean of all the stations the warmest season was that of 1896, 3°·2 above the normal, and the coldest 1885, 2°·7 below normal.

The Rio observations show that this part of Brazil is not in general affected by the conditions that govern the temperature variations in the middle latitudes of Argentina and Chile, although in 13 years it is in agreement.

Efforts to correlate the S. American winter temperature variations from 1876 to 1911 with concurrent atmospheric conditions in other regions have, with one partial exception, yielded negative results. The temperature variations at Cape Town during the 21 years 1888 to 1908 agree, however, in the main with the S. American values, as will be seen from the following table showing the departures from the normal for Cape Town and Santiago.

Departure from Normal of the Mean Temperature from May to August, from 1888 to 1908.

	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898
	°	°	°	°	°	°	°	°	°	°	°
Cape Town	—·6	— ·1	— ·8	+ ·4	—1·0	— ·2	—·4	—1·5	+ ·8	+1·2	+·4
Santiago...	—·3	—1·5	—2·2	+1·1	—2·5	—2·1	—·6	+ ·7	+3·7	+ ·4	—·7

	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	Mean.
Cape Town	+·9	+1·1	+1·1	+1·0	—1·3	+ ·2	·0	—1·3	—·4	+ ·3	56·0
Santiago...	+·9	+1·1	+ ·8	— ·2	—1·0	+2·1	+1·9	— ·6	—·3	+ ·1	48·2

The correlation co-efficient is 0·50, and probable error 0·19.

The years of pronounced disagreement were thus 1895, 1898, and 1902, the sign of the departure from the mean in the other 18 years being the same. In the three years 1909-1911 the correlation breaks down completely. The Cape Town mean temperatures are the averages of the maximum and minimum values published monthly in Symons's Magazine.

AUCKLAND AND ALICE SPRINGS.

On comparing the mean temperature at Auckland, New Zealand, for the second quarter of the year, with the values at Alice Springs, Australia, for the last quarter, it was found that from 1892 to 1906 the former was an index of the latter. The departures from the normal of the 15 years under review were as follows :—

	1892	1893	1894	1895	1896	1897	1898	1899
	°	°	°	°	°	°	°	°
Auckland, April to June...	+1·1	+1·6	·0	— ·7	+ ·9	+1·4	+ ·3	—1·1
Alice Springs, Oct. to Dec.	+2·1	+1·5	+·2	—1·0	+3·1	+2·1	+1·2	+ ·2

	1900	1901	1902	1903	1904	1905	1906	Mean.
Auckland, April to June...	+1·9	+ ·2	—·8	—1·2	— ·7	— ·7	—1·6	57·0
Alice Springs, Oct. to Dec.	+2·3	+1·8	—·6	—3·5	—1·6	—1·4	—3·0	78·7

In this case the co-efficient of correlation is as high as 0·86, and the probable error 0·13.

At both stations the mean temperature is the average of the max. and min., the values referring to Auckland being extracted from this Magazine or the New Zealand Meteorological Reports; while for the Alice Springs data we are indebted to Mr. H. A. Hunt, Commonwealth Meteorologist.

SYDNEY, N.S.W., AND SAN FRANCISCO, CAL.

From 1864 to 1889 a well-marked relation was apparent between the mean temperature at Sydney from May to August and the rainfall at San Francisco during the period October to April following. When the temperature at the one station was below the normal in the May to August period the aggregate rainfall during the period October to April following was deficient at the other place, and *vice versa.*

The mean May to August temperature at Sydney during the above period was 55°·2, and the mean San Francisco rainfall from October to April was 24·0 in. The departures from the normal during the period under review were as follows, the rainfall being given as a percentage above or below the normal. Under the first year, 1864, is given the San Francisco rain data for the seven months ending with April, 1865.

	1864	1865	1866	1867	1868	1869	1870	1871	1872
Sydney Temp., May to August ... deg.	—·1	—1·4	+1·0	+1·3	+·2	+·1	—·4	+·3	—·9
San Francisco Rain, Oct.–April following %	—1	—12	+45	+60	—11	—21	—43	+27	—35

	1873	1874	1875	1876	1877	1878	1879	1880	1881
Sydney Temp., May to August ... deg.	+1·3	−1·0	+·4	+·2	+1·1	−·7	−1·3	−·4	−·4
San Francisco Rain, Oct.-April following %	0	−20	+29	−57	+46	−11	+6	+21	−35

	1882	1883	1884	1885	1886	1887	1888	1889	Mean.
Sydney Temp., May to August ... deg.	−·3	+·2	+·9	+·8	+·4	−·7	−·3	+·8	55·2°
San Francisco Rain, Oct.-April following %	−32	+21	−27	+35	−22	−34	−14	+86	24·0 in.

In the following diagram (Fig. 11), the actual values are shown in graphic form, the Sydney data being derived from a table kindly sent by Mr. H. A. Hunt, while the San Francisco rain has been taken from *Bulletin W* issued by the U.S. Weather Bureau.

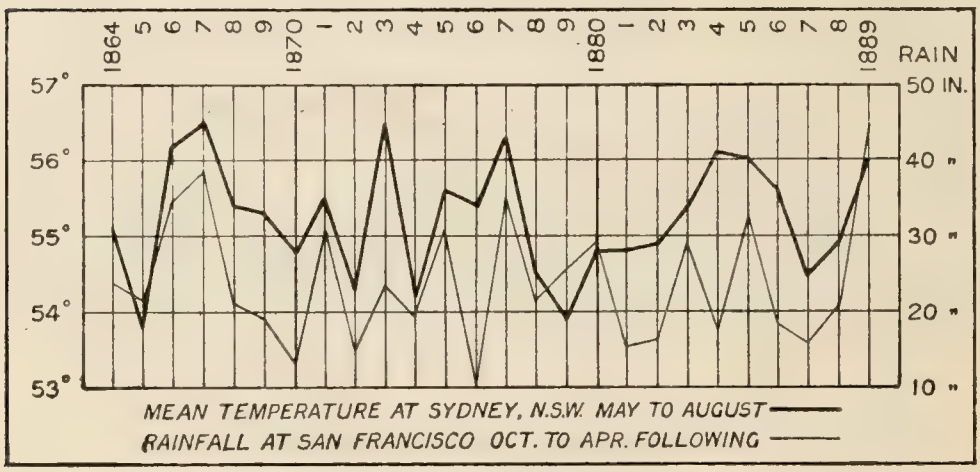

Fig. 11.

The correlation co-efficient is 0·54, and the probable error 0·16.

SOUTH ORKNEYS AND KIMBERLEY.

Since the South Orkney observatory was established in 1903 the August and September temperature there has been a direct index of the temperature at Kimberley, South Africa, during the three months following. The South Orkney data are taken, by kind permission of Mr. W. G. Davis, from Vol. **17** of the Anales (Part II.) now in course of publication by the Argentine Meteorological Office, while the Kimberley data are from Dr. Sutton's recent paper on "A Preliminary Survey of the Meteorology of Kimberley," published in the *Trans. Roy. Soc. of South Africa*, Vol. **3**, p. 226.

The mean temperatures are as follows, being shown graphically in Fig. 12.

	1903	1904	1905	1906	1907	1908	1909	1910	1911	Mean.
S. Orkneys, Aug. & Sept.	16°·0	16°·6	24°·2	16°·9	9°·9	23°·8	19°·3	16°·5	23°·3	18°·5
Kimberley, Oct. to Dec.	74·6	74·3	76·4	73·1	72·7	75·0	74·7	73·2	77·6	74·6

Expressed as departures from the normal we have :—

	1903	1904	1905	1906	1907	1908	1909	1910	1911
S. Orkneys ...	—2°·5	—1°·9	+5°·7	—1°·6	—8°·6	+5°·3	+°·8	—2°·0	+4°·8
Kimberley ...	·0	— ·3	+1·8	—1·5	—1·9	+ ·4	+·1	—1·4	+3·0

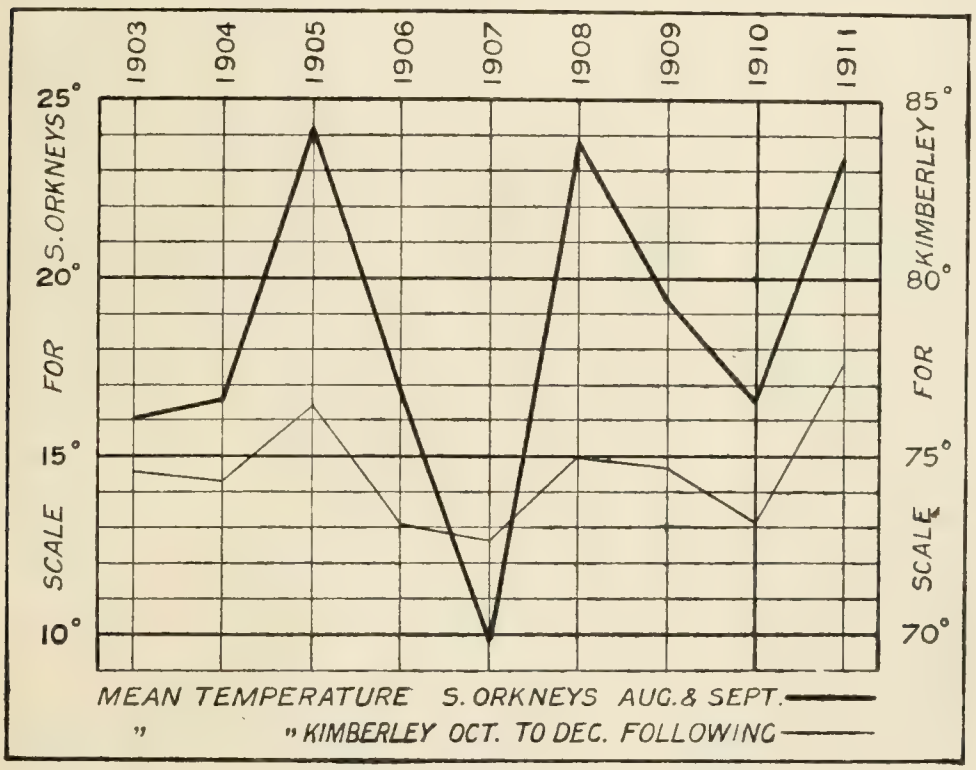

Fig. 12.

From these values the co-efficient of correlation works out 0·82, and the probable error 0·19.

The temperature during August and September at the South Orkneys is largely dependent on the ice conditions of the ocean surrounding, and as the ice is moving east-north-east it is feasible to suppose that the temperature prevailing over South Africa is related in some way to the antecedent conditions in the great Southern Ocean. The relation is not a direct one, however, since the temperature at Cape Town for the three months under review is not in harmony with that of Kimberley or the South Orkneys.

BAROMETRIC PRESSURE AT THE SOUTH ORKNEYS AND HEIGHT OF THE PARANA IN DECEMBER.

In the month of December the height of the River Parana at Rosario (lat. 33° S., long. 61° W.), and the mean barometric pressure at Laurie Island, South Orkneys, are intimately related. When the barometric pressure in the sub-Antarctic is high the height of the Parana is also high, and when pressure is low in the far south the Parana is also low. The explanation is that the height of the Parana, as measured at Rosario, really depends on the rainfall over the south of Brazil and adjacent areas, and this is related to the barometric pressure. There is at this time of year a marked tendency for high pressure to the south and south-east of Cape Horn,

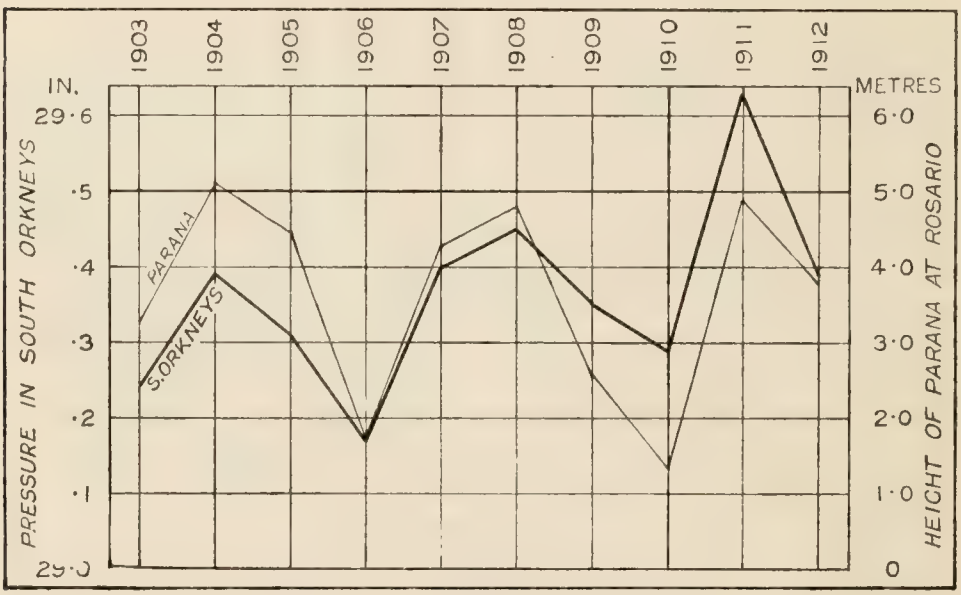

FIG. 13.

and it is not unreasonable to suppose that when the Grahams Land lobe of the Antarctic anti-cyclone is intensified the pressure over the interior of Brazil will be correspondingly diminished, and *vice versa*. The following are the values of barometric pressure in December at the S. Orkneys and the height (in metres) of the Parana at Rosario, the former being derived from the volume already mentioned, and the latter from the records in possession of the Hydrometric Branch of the Argentine Meteorological Office.

December.	1903	1904	1905	1906	1907	190
S. Orkneys, Barometer ... (inches)	29·24	·39	·31	·17	·40	·4
Parana at Rosario ..... (metres)	3·27	5·11	4·44	1·70	4·27	4·8

	1909	1910	1911	1912	Mean
S. Orkneys, Barometer ... (inches)	·35	·29	·63	·39	29·3
Parana at Rosario ..... (metres)	2·57	1·32	4·92	3·79	3·6

The barometric observations are at station level and require a correction of + ·07 inch to reduce them to sea-level and gravity. The above data are shown in Fig. 13, and the annexed table gives the departures from the normal.

	1903	1904	1905	1906	1907
S. Orkneys, Pressure ..... (inches)	— ·12	+ ·03	— ·05	— ·19	+ ·04
Height of Parana..... (metres)	— ·35	+1·49	+ ·82	—1·92	+ ·65
	1908	1909	1910	1911	1912
S. Orkneys, Pressure ..... (inches)	+ ·09	— ·01	— ·07	+ ·27	+ ·03
Height of Parana..... (metres)	+1·18	—1·05	—2·30	+1·30	+ ·17

Hence the only year of divergence as regards sign was 1905, and it will be seen that the curves follow each other very closely from one year to another.

The correlation co-efficient is in this instance 0·70, and probable error 0·23.

CONCLUSION.

In conclusion, as regards the practical value of this class of research, some glimpses of which have been obtained in the foregoing series of articles, while it certainly opens up prospects of the possibility of long range weather forecasts in some instances, yet until we obtain some definite knowledge regarding the physical processes by which the observed correlations are brought about and the permanence or otherwise of the leading features, we cannot with any degree of confidence utilise the information. Are the correlations such as that observed from 1876 to 1894 between the Trinidad rainfall from April to September and that at Ajo for the following six months, fortuitous phenomena or subject to a cyclical repetition? If so, will the next period of agreement be of the same length as that already observed? Time only can settle such questions, unless we can in the meanwhile obtain a clue as to what is at the root of the matter. It is almost certain that the inter-action is world-wide, but even to-day we have not weather data for many regions to enable us to investigate the meteorological inter-relations existing between regions far distant.

We must, therefore, make an examination of the normal meteorological conditions, based on world maps deduced from the greatly extended, improved and homogeneous, mass of material that has accumulated since Buchan—a quarter of a century ago—issued his celebrated "*Challenger*" *Report on Atmospheric Circulation.* As an essential feature of this study another polar—a bi-polar—campaign is required with numerous fixed stations at work during a minimum period of $2\frac{1}{2}$ years, so as to give a complete representation of the meteorology of the Arctic and Antarctic zones. In this connection a station at the South Pole should be set up and maintained — this is merely a matter of expense, combined with mproved methods of transport. Stations are also required on the

islands strewn over the ocean wastes, particularly those in the southern hemisphere. The equatorial belt should be specially investigated, and research ships should be kept cruising about in areas not covered by ordinary trade routes, nor having islands available on which to establish observatories. Materials for the preparation of daily maps of the whole globe would thus be ready, the study of which would pave the way for the application of the data to the elucidation of the utilitarian problems in hand. The International Arctic campaign of the years 1882-83 was restricted to the northern hemisphere, the Antarctic co-operation of 1901-1904 stopped short at the thirtieth parallel of south latitude; we require now the extension of the area of synoptic observation over the whole world.

There is no reason why the preliminaries of such a scheme should not begin at once, at least in so far as the getting of normals is concerned. There are apparently no Buchans to tackle this work single-handed, nor is this indeed desirable considering the enormous labour and delay involved in individual effort. A Bureau to deal with World-Meteorology is required, one of the first duties of which would be to prepare the homogeneous normals referred to above, and especially to discuss abnormals and to explain their causes. A good deal of trouble would accompany this preliminary work in so far as the meteorology of the ocean is involved, because there are few means available over a series of years for specific areas from which abnormals could be discussed, while large portions of the ocean are practically unrepresented by data from one year to another. For example, there is little difficulty in dealing with the monthly abnormals of a fixed land station; but if we wish to discuss the same data for, say, any given 10° ocean square, we should have—except in rare instances already specially investigated—to go to the individual logs contained in the various Hydrographical and other offices dealing with Maritime Meteorology, and combine the whole, so as to get means for each of the months and the years of the period we wish to investigate. This appears to be the great stumbling-block in the work outlined above, but its subjugation is practically a matter of co-operation, organization and expense.

The principal bar to progress in working out the problems associated with long range weather forecasting, doubtless lies in the inadequate State support given to most Government Meteorological Services. That the Powers that be recognize their utility is not disputed, since they would not otherwise exist, but in almost every case the extensions which an enlightened Director would like to initiate are hampered and curtailed through want of funds. Research work, on which progress really depends, has been and continues to be largely subordinated to labours of a routine character, being done in what may be ironically termed "the spare time" of an office. Data arrive in shoals without cessation and most of the available resources are expended in their reduction and publication. No one will deny for a moment that invaluable and

indeed, indispensable, information is not thus being gathered, and that the seeds of modern methods, incorporating much patient research, are not yielding valuable fruit. But the field of vision is too contracted, because, when such an occurrence as a great frost, heat wave, drought, rainy period, or indeed any phenomenon of an important character takes place, while we may rely on the production of a report, excellent, one might say, in many cases perfect, in its—from a geographical stand-point—local aspects, there is seldom a line as to what has taken place in regions far distant. Our horizon seems to be narrow, and we do not stop to speculate as to whether, for example, the failure or intensification of the rainy season in some portion of the sub-tropical or equatorial regions was not responsible for the unseasonable weather that manifested itself, perhaps, several months later, in some portion of the North or South Temperate Zones.

The establishment of a World Bureau seems the only way to meet the situation, and the sooner such an institution is set on foot the better. It is most desirable that knowledge, in so far as it bears on such practical and vital questions as are involved in long range forecasting, should be common property, disseminated through the agency of a responsible institution.

What would the public think if a band of speculators in grain formed a little bureau of this character for their own special benefit? One can readily picture the economic disturbance that would be associated with the cornering of, say, the world's wheat supply, based on fore-knowledge of a failure of the crops over the greater portion of the wheat belts of the globe. Doubtless for some time those taking part in operations of this nature would still be gamblers, but the dice would be heavily loaded.

In drawing to a close what many may be inclined to designate a somewhat unprofitable, and in some respects even bizarre, investigation, it may be pointed out that the method of using the preceding weather in one part of the Earth as a means of arriving at a knowledge of what will subsequently take place in another part, has already had practical application. The probable intensity of the Indian Monsoon is arrived at by just such methods, which are also successfully employed in the determination of the height of the Nile flood. Hunt, in Australia, is obtaining cable information from South America and other regions, which he is making practical use of, and there is no doubt that the methods described, initiated by the genius of Hildebrandsson, are capable of wide application. In spite of the apparently fortuitous and irregular manner in which correlations between pairs of stations begin, persist and terminate, the impression gained is that there is a regularity underlying the seemingly capricious nature of the observed phenomena. In other words, the "action centres" of the globe are probably subject to a cyclical oscillation of a more or less fixed period, and the uncertainty underlying the persistence of correlation and non-correlation is due to most of

the pairs of stations utilized being located not in "action centres" but in transitional zones; some, doubtless, coming at intervals under the influence of more than one pair of "action centres."

In this connection it would be most desirable to adopt the method of iso-correlational lines recently employed by Mr. J. I. Craig* and Prof. Exner of Innsbruck† in two interesting and highly important papers. This method was independently thought of in connection with the Ajo–Trinidad correlation (see pp. 19-20), but owing to lack of stations could not be adopted.

It is, of course, obvious that the treatment of the problem of "centres of action" in this way would help materially towards the definition of the areas involved in any correlation observed between two distant places. The difficulty would be to settle on the period to be discussed, especially if the area were a wide one. One part of such an area might be in sympathy with the base station for the whole period to be examined, say 35 years, whereas another, probably a more distant portion, might show a correlation for only the first half of the period, coming during the second half under the influence of another "action centre" or even occupying a neutral zone for the time being.

One way of clearing up the point would be to examine the data for those stations in north-western Europe for which we possess long-period records, extending in many cases over the last 150 years. If correlations, either simultaneous, or separated by an interval of time, flashed up between pairs of stations and disappeared for regular periods, then the recurring nature of the occurrence would be recognised, and a distinct advance made on the, at present, unsatisfactory and, doubtless to many, unconvincing situation.

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* "A Temperature See-Saw between England and Egypt." See *Symons's Meteorological Magazine*, Vol. 48, p. 178.

† Exner, Felix M.: "Über monatliche Witterungs anomalien auf der nördlichen Erdhälfe im Winter." Wien, 1913. S. A. Sitzber der K. Akad. der Wiss. in Wien. Math.-nat. Klasse. Bd. CXXII, Abt. IIa, Juni, 1913.

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